Acquisition Directorate
Research & Development Center

Report No. CG-D-07-09

Phase 1 Summary Report on AIS Transmit Project (Environmental Message)

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16. Abstract (MAXIMUM 200 WORDS)

The Automatic Identification System (AIS) is an autonomous and continuous broadcast system that exchanges maritime safety/security information between participating vessels and shore stations. United States Coast Guard (USCG) Shore Forces Vessel Traffic Services (VTS) Division requested the USCG Research and Development Center's (RDC) to identify and develop requirements for marine information that could be broadcast by USCG VTS Centers using the AIS binary message feature. A test bed, at the Cooperative VTS (CVTS) in Tampa, FL, has been established to test concepts, ideas, and draft standards.

A requirements study was performed concluding that: data rather than voice was preferred; flexibility in type and frequency of information is very important; information needs to be based on area of operation; all users want information displayed in a way that is user-friendly, clear, uncluttered; mariners do not want to be overwhelmed with too much or useless information; and equipment manufacturers and users should decide how best to display information on existing shipboard systems.

Phase 1 of the test bed began on September 12, 2008 with the Tampa Bay Pilots as the test user group using the new Environmental binary message. So far, feedback from the pilots has been predominantly positive and no negative impacts on the Very High Frequency (VHF) Data Link (VDL) loading have been experienced.

The test bed has enabled RDC to develop and test new message formats for national and international adoption, better understand operational procedures for transmit of binary messages, and start to study the impact of these messages on the VDL. The experience gained (lessons learned) will help in the implementation of the operational system as part of the USCG Nationwide AIS Program. Phase 2 of this test bed consists of implementing Area Notices and Phase 3 consists of implementing Waterways Management Messages.

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EXECUTIVE SUMMARY

The Automatic Identification System (AIS) is an autonomous and continuous broadcast system that exchanges maritime safety/security information between participating vessels and shore stations. In addition to providing a means for maritime administrations to effectively track the movement of vessels in coastal waters, AIS can be a means to transmit information to ships in port or underway that contributes to safety-of-navigation and protection of the environment. This includes meteorological and hydrographic data, carriage of dangerous cargos, safety and security zones, status of aids-to-navigation, and other port/waterway safety information. In the United States, it is intended that this information be transmitted from shore-side AIS Base Stations in binary message format as part of expanded Vessel Traffic Services (VTS) provided by the United States Coast Guard (USCG).

Commandant (CG-7413) - Shore Forces Vessel Traffic Services Division requested the U.S. Coast Guard Research and Development Center's (RDC) assistance to identify and develop requirements for marine information that could be broadcast by Coast Guard VTS Centers using the AIS binary message feature. The objective of this research is to improve the safety and efficiency of vessel navigation especially within VTS areas. The goal is to implement enhanced AIS Coast Guard-wide. To reach this goal, a test bed has been established to test concepts, ideas, draft standards, etc. prior to CG-wide implementation. After some analysis of alternatives it was decided to establish the test bed at the Cooperative VTS (CVTS) Tampa, FL.

In December 2007, RDC with support from Alion Science and Technology (Alion) completed and delivered a Requirements Report that documented the requirements for AIS binary messaging. In preparing the report, representatives of each segment (information providers and information disseminators, users (mariners), and shipboard equipment manufacturers) were contacted. Some of the key conclusions (which drove design considerations for the binary messages and the test bed) from the Requirements Report were:

- Data rather than voice was preferred
- Flexibility in type of information and frequency is very important; information needs to be based on area of operation
- All users want information displayed in a way that is user-friendly, clear, uncluttered
- Mariners do not want to be overwhelmed with too much or useless information
- Equipment manufacturers and users are best suited to decide how to display information on existing shipboard systems

In 2004, the International Maritime Organization (IMO) established seven AIS binary messages as the basis for initial testing of the shore-to-ship transmission of AIS; these were reviewed for possible use but were found to not meet the needs identified in the Requirements Report. A working group called "The Expanded Use of AIS within VTS" was thus established under the Radio Technical Commission for Maritime Services (RTCM) Special Committee (SC) 121 to develop the AIS binary messages necessary to transmit the desired information. Working with National Oceanographic and Atmospheric Administration (NOAA) Physical Oceanographic Real-Time System (PORTS), NOAA National Data Buoy Center (NDBC), US Army Corps of Engineers (USACE), mariners and the shipboard equipment manufactures, the Working Group developed an environmental message format that would accommodate meteorological and hydrological data throughout the U.S.

The AIS binary message test bed was established in Tampa Bay and commenced operations on 12 September 2008. Participants include the USCG RDC, NOAA, CVTS Tampa, and the Tampa Bay Pilots. The first phase consisted of setting up the Tampa Test Bed for transmission of the new Environmental binary message. Most of the work in establishing the test bed was to develop the software needed to implement binary message transmission: the Fetcher/Formatter, Queue Manager, and AIS Radio Interface software. Phase 2 consists of implementing Area Notices and Phase 3 consists of implementing Waterways Management Messages.

The test bed has now been in operation for approximately 7 months. During the course of the Phase I trial, data was recorded both manually and automatically. The pilots were asked to log feedback manually after each transit. Data has also been recorded continuously at each of the software processes: Fetcher/Formatter, Queue Manager, and IP2Comm enabling post-analysis to be done on the messages sent. So far, feedback from the pilots on the test of AIS binary messaging has been predominantly positive and no negative impacts on the Very High Frequency (VHF) Data Link (VDL) loading have been experienced. The AIS VDL is composed of a finite number of slots that are reserved by users. There is a concern that these slots can be fully utilized in heavy traffic situations; in which case, the addition of binary messages would negatively impact the overburdened capacity.

CVTS Tampa has provided a good development environment for testing AIS binary messages. The test bed is able to create and deliver binary messages which mariners can use aboard ship. The test bed has enabled RDC to develop and test new message formats and start to study the impact of these messages on the VDL. In addition, the operation of the test bed has given RDC experience in binary messaging allowing lessons-learned to be developed. As we proceed with Phase 2 and 3 of this test bed, the Sector Command Center Operator and VTS Operator will be more involved with the creation of the messages to be broadcast. These messages will communicate dynamic information concerning a specified geographic area, line or point. The information will convey pertinent time-critical navigation safety information to mariners. It is highly recommended that the experience gained from this test bed be incorporated into Nationwide AIS (NAIS) Increment 2 development.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

AI	Application Identifier
AIS	Automatic Identification System
Alion	Alion Sciences and Technology
AOR	Area Of Responsibility
ARI	AIS Radio Interface
ARPA	Automatic Radar Plotting Aid
ATON	Aids to Navigation
BBM	Broadcast Binary Message
BNTM	Broadcast Notice to Mariners
CCG	Canadian Coast Guard
CG	Coast Guard
CRIS	Coastal and River Information Service
COTP	Captain of the Port
CSV	Comma Separated Value
CVTS	Cooperative Vessel Traffic Service
DAC	Designated Area Code
DGPS	Differential Global Positioning System
ECDIS	Electronic Chart Display Information System
ECS	Electronic Chart System
FI	Function Identifier
FM	Frequency Modulation
GPS	Global Positioning System
HQ	Headquarters
ID	Identification
IMO	International Maritime Organization
IP	Internet Protocol
ITU	International Telecommunications Union
LT	Lieutenant
LTJG	Lieutenant Junior Grade
LTCDR	Lieutenant Commander
MCTS	Marine Communications and Traffic Services
MIB	Marine Information Broadcast
MIO	Marine Information Overlay
MKD	Minimum Key Display
Msg	Message
NACC	North American Controls Corporation
NAIS	National Automatic Identification System
NDBC	National Data Buoy Center
NMEA	National Marine Electronics Association
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NOTM	Notice to Mariners
OOW	Officer of the Watch

LIST OF ACRONYMS (Continued)

OSC	USCG Operations Systems Center
PAWSS	Ports and Waterways Surveillance System
POC	Point of Contact
PORTS®	Physical Oceanographic Real-Time System
PPU	Portable Pilot Unit
QM	Queue Manager
RACON	Radar Beacon
RDC	USCG Research and Development Center
RR	Railroad
RTCM	Radio Technical Committee for Maritime Services
RTCV	Real Time Current Velocity
SC	Special Committee
SLS	Saint Lawrence Seaway
SLW	Saint Lawrence River Waterway
USACE	United States Army Corps of Engineers
TCP	Transmission Control Protocal
USCG	United States Coast Guard
VDL	Very-High Frequency Digital Link
VHF	Very High Frequency
VTS	Vessel Traffic Services

1 INTRODUCTION

1.1 Background

The Automatic Identification System (AIS) is an autonomous and continuous broadcast system that exchanges maritime safety/security information between participating vessels and shore stations. In addition to providing a means for maritime administrations to effectively track the movement of vessels in coastal waters, AIS can be a means to transmit information to ships in port or underway that contributes to safety-of-navigation and protection of the environment. This includes meteorological and hydrographic data, carriage of dangerous cargos, safety and security zones, status of aids-to-navigation, and other port/waterway safety information. In the United States, it is intended that this information be transmitted from shore-side AIS Base Stations in binary message format as part of expanded Vessel Traffic Services (VTS) provided by the United States Coast Guard (USCG).

Commandant (CG-7413) - Shore Forces Vessel Traffic Services Division requested the U.S. Coast Guard Research and Development Center's (RDC) assistance to identify and develop requirements for marine information that could be broadcast by Coast Guard VTS Centers using the AIS binary message feature. The objective of this research is to improve the safety and efficiency of vessel navigation especially within VTS areas. The research focuses on all stakeholder segments: information providers/disseminators, users (mariners), and shipboard equipment manufacturers in order to gather requirements and capabilities. The goals are to identify and prioritize the types of information that should be broadcast using AIS binary messages – information that is available, important to the mariner, and provided to the mariner in a timely fashion and in a usable format; and second, to develop recommendations for transmission and shipboard display standards.

1.2 Test Bed Goal

The goal is to implement enhanced AIS Coast Guard-wide where enhanced means to go beyond the ship-to-ship capability and use the AIS transmit feature to send information (e.g. meteorological and hydrographic data, carriage of dangerous cargos, safety and security zones, status of aids-to-navigation, and other port/waterway safety information) to vessels from shore. To reach this goal, a test bed has been established to test concepts, ideas, draft standards, etc. prior to CG-wide implementation. After some analysis of alternatives (see [1]), it was decided to establish the test bed at the Cooperative VTS (CVTS) Tampa, FL. This VTS operation is a cooperative venture between the USCG and the Port Authority of Tampa. Details on the original design and the implementation plan are in [2].

The test bed design includes all of the elements shown conceptually in Figure 1. The green cloud (labeled 1) consists of the External Information Providers. These are the agencies/ organizations external to the Coast Guard VTS site that have data that the VTS would like to transmit. For the Phase I implementation, the only data source is National Oceanic and Atmospheric Administration (NOAA) (the source of the Physical Oceanographic Real-Time System (PORTS®)[1] environmental data). The orange cloud (labeled 2) is the Test User Group and consists of all of the users that are participating in the test (this is not all AIS users). For Phase I, this has been the Tampa Bay Pilots using ARINC Portable Pilot Units (PPUs). The third component, the blue cloud (labeled 3) is the CG VTS. This consists of the current CVTS Tampa operations plus the addition of new functionality. The final component is the tan cloud (labeled 4) that is the Monitor Site. This monitor receives all transmitted messages to ensure that they are being transmitted as planned,

[1] Physical Oceanographic Real-Time System, see http://tidesandcurrents.noaa.gov/ports.html

collects data for later analysis, and also includes an Electronic Chart Systems (ECS) display to evaluate how the binary messages are being presented to the user.

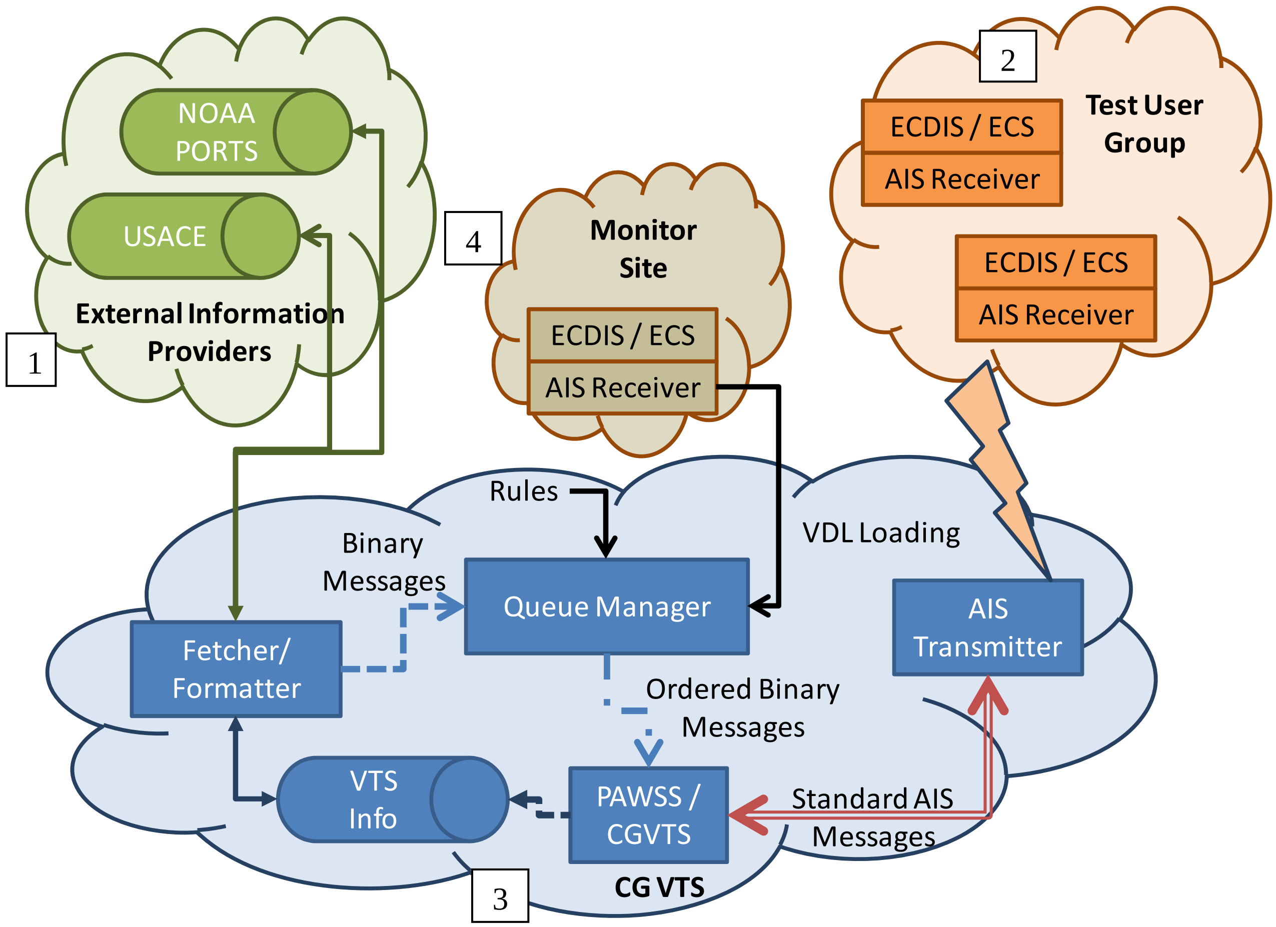


Figure 1. Test bed conceptual diagram.

1.3 Requirements Report

In December 2007, RDC, with support from its contractor Alion Science and Technology (Alion), completed and delivered a Requirements Report (later published as [3]) that documented the requirements for AIS binary messaging. In preparing the report, representatives of each segment involved with the transmit capability (information providers and information disseminators, users (mariners), and shipboard equipment manufacturers) were contacted. In the information providers and disseminators category, project personnel visited 6 CG VTSs (New York, Louisville, San Francisco, Sault Ste Marie, Houston, and Puget Sound) and one Canadian MCTS (Sarnia), and contacted 2 others (Tampa and Los Angeles-Long Beach) for input. In addition, project personnel met with representatives from NOAA and the U.S. Army Corps of Engineers (USACE) and conducted phone interviews with Canadian CG and Saint Lawrence Seaway (SLS) personnel. In the users' category, project personnel collected input from about 15 user groups from locations in New York, Louisville, Houston, San Francisco, and Puget Sound. This was done mostly via phone and e-mail interviews with some face-to-face meetings. In the manufacturers' category, project personnel contacted and received information from 5 major manufacturers of AIS-enabled Electronic Chart Systems (ECS) software.

During the data collection, the representatives from each segment were asked for their input on about 20 possible data items that could potentially be transmitted using AIS binary messages. In addition, they were asked for input on additional items for the list. These responses were tabulated and evaluated and those most important to all segments were identified. This yielded a short list of 11 items shown in Table 1. The information items were also categorized in the table to group them into a small number of message types. Three of these message types became the three phases of the effort.

Table 1. Mapping of desired information to message types.

Information	AIS Message
Tides and currents	Environmental
Water levels	Environmental
Emergency Messages	Current Message 12/14
AtoN outages / changes	Current Message 21 or Zone Information
Lock order	Waterways Management
Ice Advisory	Zone/Area Information
Dredging locations / information	Zone/Area Information
Security zone locations / information	Zone/Area Information
Fog	Environmental or Zone Information
Marine info (regattas, events)	Zone/Area Information
Anchorage management	Zone/Area Information

Some of the key conclusions from the Requirements Report were:

- Data rather than voice was preferred
- Flexibility in type of information and frequency is very important; information needs to be based on area of operation
- All users want information displayed in a way that is user-friendly, clear, uncluttered
- Mariners do not want to be overwhelmed with too much or useless information
- Equipment manufacturers and users are best suited to decide how to display information on existing shipboard systems

These conclusions drove design considerations for the binary messages and the test bed. Phase I focused on the development of the binary message to transmit environmental data (tides, currents, etc). Phase 2 consists of implementing Zone/Area Information; and Phase 3 consists of implementing Waterways Management Information. This report focuses on Phase 1. A follow on report at the conclusion of this effort will discuss all three phases.

2 PHASE 1 - ENVIRONMENTAL MESSAGE

2.1 IMO Message

In 2004, the International Maritime Organization (IMO) established seven AIS binary messages as the basis for initial testing of the shore-to-ship transmission of AIS (Table 2) and published these in IMO SN/Circ.236 [4]. Of these test messages, two cover environmental-type data: applications #1, and #4. These were reviewed for possible use but were found to not meet the needs identified in the Requirements Report. In particular, the existing message will only send data for multiple parameters at one location. If additional readings of a similar parameter (e.g., current profile) need to be disseminated, multiple binary messages must be sent, unnecessarily loading the Very High Frequency (VHF) Data Link (VDL). If only one parameter is available, the entire two-slot message must be sent, rather than a smaller message containing the available data. The Requirements Report determined that many types of environmental data are related and have similar properties. In particular, this includes data from NOAA PORTS sensors. Furthermore, it makes more sense from a VDL loading perspective to transmit static data such as station identification and location less frequently than dynamic data from the sensor like water current or level which is not possible with the Circ.236 messages.

Table 2. IMO proposed binary messages.

Message #	Purpose
1	Meteorological and hydrographic data
2	Dangerous cargo indication
3	Fairway closed
4	Tidal window
5	Extended ship static and voyage related data
6	Number of persons on board
7	Pseudo-AIS targets

2.2 RTCM Message

The Radio Technical Commission for Maritime Services (RTCM) is an international non-profit scientific, professional and educational organization. RTCM Special Committees (SC) within the organization provide a forum in which government and non-government members work together to develop technical standards and consensus recommendations in regard to issues of particular concern. A working group called "The Expanded Use of AIS within VTS" was established under SC 121 to develop the AIS binary messages necessary to transmit the information types listed in Table 1.

Working with NOAA PORTS®, NOAA National Data Buoy Center (NDBC), US Army Corps of Engineers, mariners and the shipboard equipment manufacturers, the Working Group developed an environmental message format that would accommodate meteorological and hydrological data throughout the U.S. The Environmental Message is intended for a wide variety of environmental data, including: current, water level, water temperature, visibility, and air gap. The message is designed to include the ability to handle both real-time and forecast data. It is also very flexible in that the message can be anywhere from 1-5 slots depending on the quantity of data to be transmitted and the VDL loading. One message can contain data from 1-8 sensors, and can mix and match the data as needed (a message with 1 sensor report can be sent in 1 slot, a message with 8 sensor reports takes 5 slots). For example, if the frequency of water level information is higher than current flow, yet all the sensors are at one location, messages can be created to handle various frequency and location requirements. Each sensor report carries the dynamic or static information relating to a specific sensor; the various sensor reports are listed in Table 3. The Environmental Message was finalized and published in May 2008; since that time there have been two minor revisions that have clarified the field definitions, but the binary format has not changed. This is the message being used in the Tampa test bed; the details are contained in Appendix A.

It is important to note that the environmental message has been submitted by the International Maritime Organization (IMO) Correspondence Group on AIS Binary Messages to IMO Nav/55 for consideration and adoption internationally. RTCM is also finalizing a RTCM standard for the environmental message for national adoption.

Table 3. Environmental message sensor report types.

Report #	Description
0	Sensor Site Location
1	Station ID
2	Wind
3	Water level
4	Current Flow Report v1 - report speed and direction
5	Current Flow Report v2 - report north- and east- ocean current vector components (u- and v-components)
6	Horizontal Current Flow Current
7	Sea state
8	Salinity
9	Weather
10	Air gap / Air draft
11-15	Reserved for future use

3 TAMPA TEST BED

The AIS binary message test bed was established in Tampa Bay and commenced operations on 12 September 2008. The participants, hardware, and software for Phase I are described in the following sections.

3.1 Key Participants

3.1.1 USCG R&D Center

This project is an effort run by RDC. RDC handles the interactions with the project sponsor, USCG HQ, as well as provides oversight and management. RDC is supported by contractors from Alion Science & Technology who are responsible for the implementation and running of the test bed. Additional support is provided by University of New Hampshire (UNH).

3.1.2 NOAA

The National Ocean Service (NOS) is responsible for providing real-time oceanographic data and other navigation products to promote safe and efficient navigation within U.S. waters. This is being done using the Physical Oceanographic Real-Time System (PORTS®). The data is accessed from NOAA's server in Silver Spring, MD via the Internet. The sensor locations and the data available from each location can be seen in Figure 2.

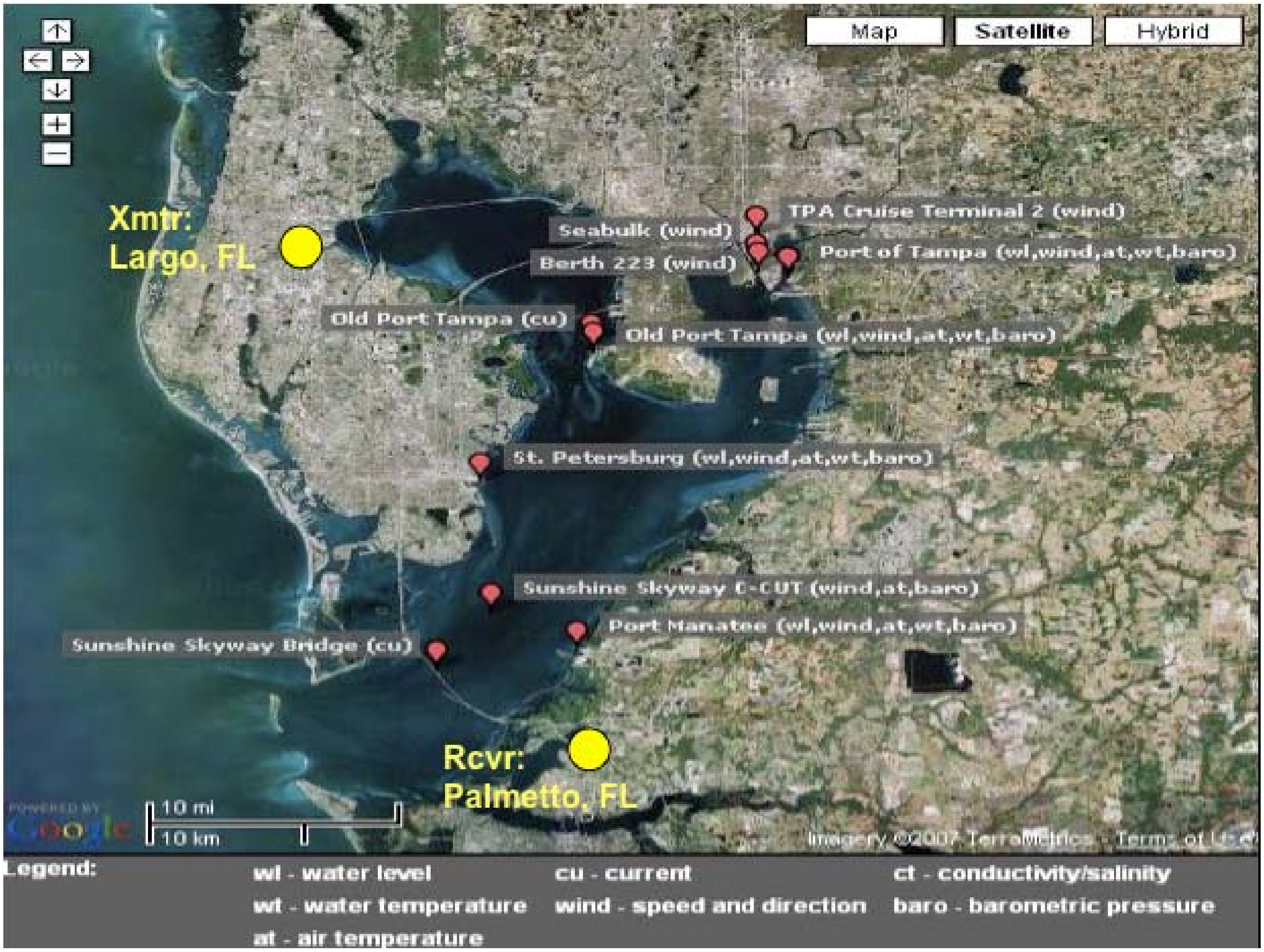
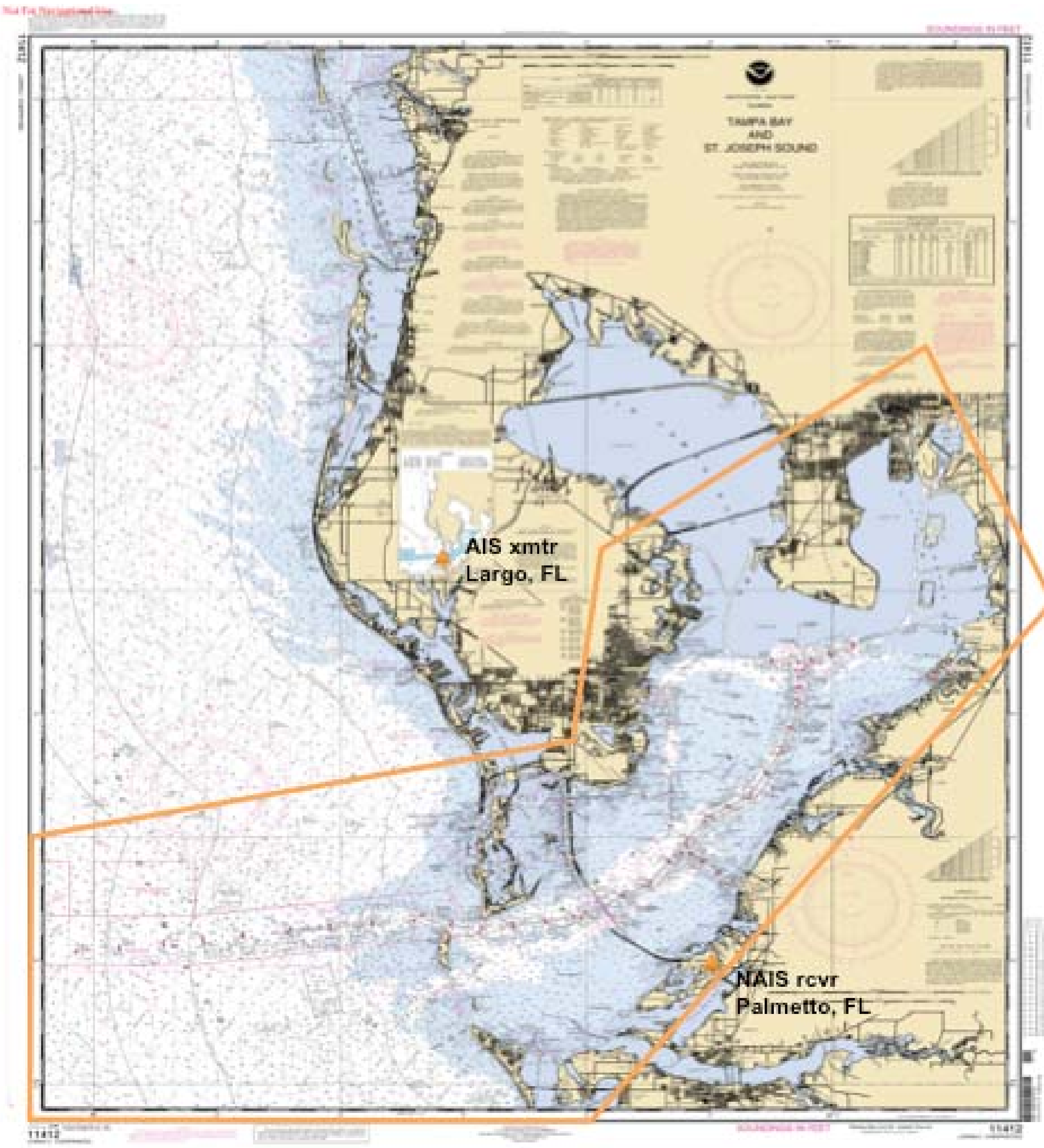


Figure 2. NOAA PORTS sensor locations in Tampa Bay.

3.1.3 USCG Cooperative VTS (CVTS) Tampa

The VTS in the Tampa Bay area is a cooperative effort between the USCG, Tampa Port Authority, the Tampa Bay Harbor Safety and Security Committee, and the ports of Tampa, Manatee, and St. Petersburg. The traffic system is focused on the safe movement of all vessels sailing the navigable waters within a 35-mile radius of a centralized sea buoy and all waters east of the Sunshine Skyway Bridge. This area includes Old Tampa Bay, south of the Gandy Bridge, and all waters of the Tampa Bay and Hillsborough Bay. This Area of Responsibility (AOR) is contained on Chart 11412 (Figure 3). The CVTS AIS transmitter is located in Largo and is maintained under contract by L-3 Communications. In addition, there is a Nationwide AIS (NAIS) receiver located in Palmetto, which is used as the monitor site receiver.

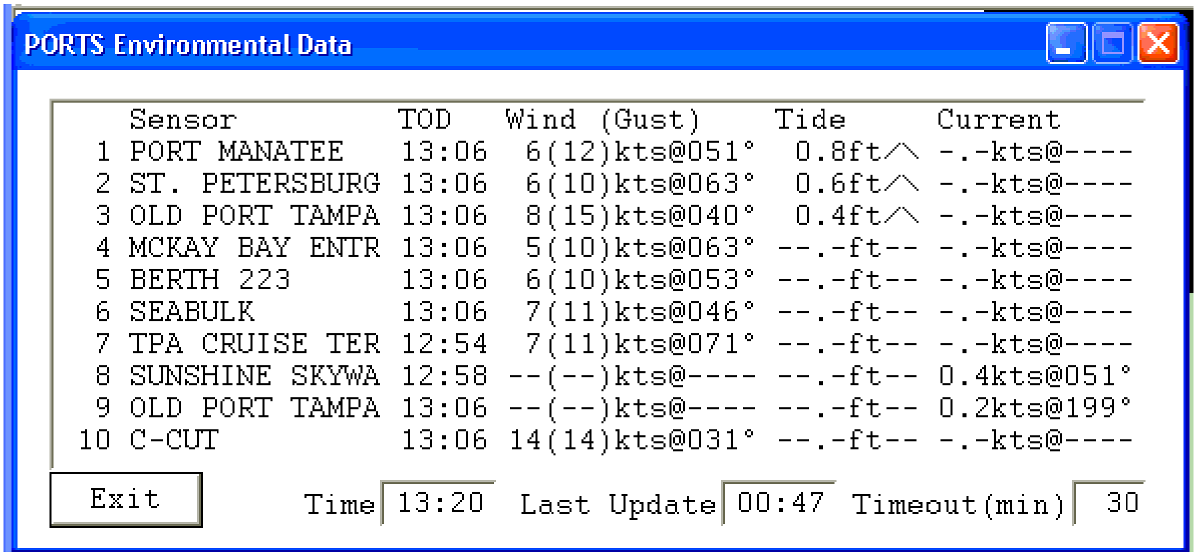


Orange outline = Approximate CVTS Tampa AOR
Orange triangles = Approximate transmitter and receiver sites

Figure 3. Chart 11412 - Tampa Bay and St. Joseph Sound.

3.1.4 Tampa Bay Pilots

The Tampa Bay Pilots provide pilotage service to commercial vessels entering the port of Tampa (the largest port in Florida). They have provided the user group for the Phase I test bed. They are able to receive, decode, and display the Environmental messages using their ARINC PilotMate software. A screenshot of what the decoded Environmental message looks like on their software is contained in Figure 4.



	Sensor	TOD	Wind (Gust)	Tide	Current
1	PORT MANATEE	13:06	6(12)kts@051°	0.8ft↗↘	-.-kts@----
2	ST. PETERSBURG	13:06	6(10)kts@063°	0.6ft↗↘	-.-kts@----
3	OLD PORT TAMPA	13:06	8(15)kts@040°	0.4ft↗↘	-.-kts@----
4	MCKAY BAY ENTR	13:06	5(10)kts@063°	--.-ft--	-.-kts@----
5	BERTH 223	13:06	6(10)kts@053°	--.-ft--	-.-kts@----
6	SEABULK	13:06	7(11)kts@046°	--.-ft--	-.-kts@----
7	TPA CRUISE TER	12:54	7(11)kts@071°	--.-ft--	-.-kts@----
8	SUNSHINE SKYWA	12:58	--(--)kts@----	--.-ft--	0.4kts@051°
9	OLD PORT TAMPA	13:06	--(--)kts@----	--.-ft--	0.2kts@199°
10	C-CUT	13:06	14(14)kts@031°	--.-ft--	-.-kts@----

Figure 4. Environmental message decode display from AIRNC PilotMate software.

3.2 Hardware

The first phase consisted of setting up the Tampa Test Bed for transmission of the new Environmental binary message. Figure 5 is a block diagram of components of the test bed and how they are connected. The test bed hardware consists of various computers (grey boxes in Figure 5) and network links (red lines in Figure 5). Most of the computers were located initially at Alion's New London office. These were moved in March 2009 to the Demonstration Lab at RDC; once the RDC relocated to New London in February 2009. An additional computer and an ARINC PPU were installed at CVTS Tampa to provide display and monitoring capabilities there. This was consolidated to a single computer in May 2009.

3.3 Software

Most of the work in establishing the test bed was to develop the software to implement the functionality indicated by the green boxes in Figure 5 and configure the government software (blue boxes). Each major piece will be discussed in the following sections.

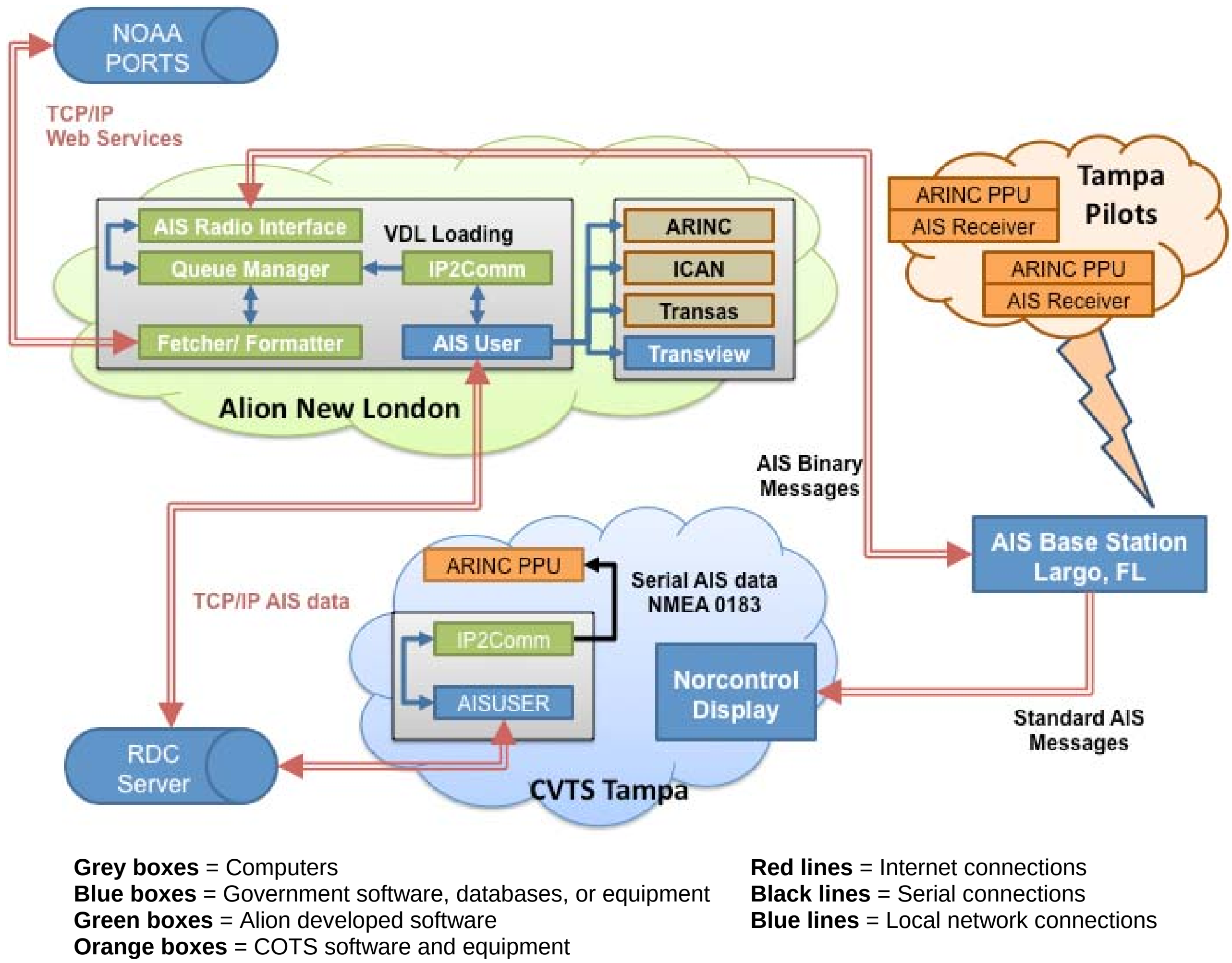


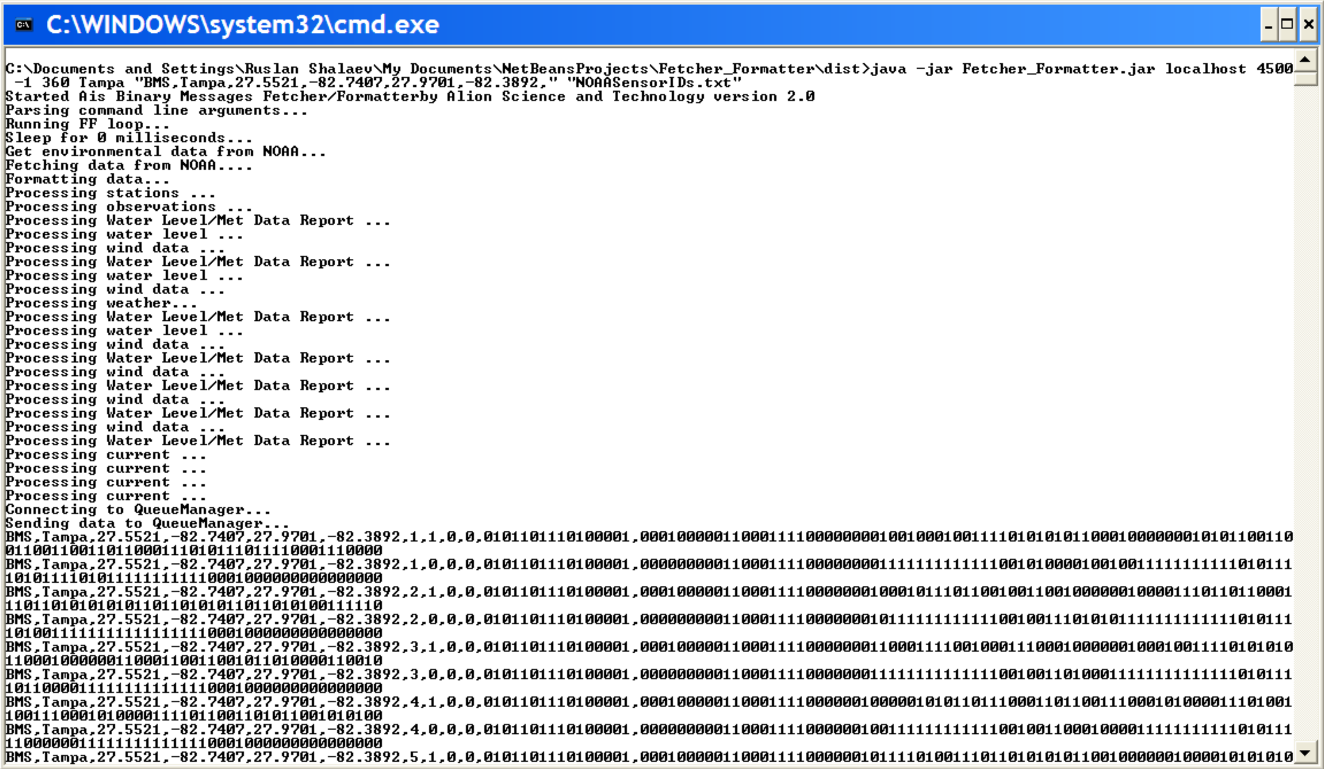
Figure 5: Tampa test bed.

3.3.1 Fetcher/Formatter (FF)

The role of the Phase I Fetcher/Formatter is to retrieve data from the NOAA PORTS database, format it into binary format, and forward the sensor reports to the Queue Manager. The interface to PORTS is through the NOAA AIS Web Services. Since NOAA provided sample interface code in Java, the Fetcher/Formatter was implemented in Java. The data is then converted into binary format and packed into Comma Separated Value (CSV) sentences along with additional information to allow the Queue Manager to manage the message queue without unpacking the binary data. Figure 6 shows an example of the FF running.

The Fetcher/Formatter accepts command-line arguments that affect program operation. Configurable parameters are:

- Queue Manager Internet Protocol (IP) Address and Port #
- Start time offset from modulo of cycle time into the hour (-1 to start immediately)
- Cycle time
- Fetcher/Formatter ID
- Message prefix
- NOAA sensor IDs look-up table file location



```
C:\WINDOWS\system32\cmd.exe
C:\Documents and Settings\Ruslan Shalaev\My Documents\NetBeansProjects\Fetcher_Formatter\dist>java -jar Fetcher_Formatter.jar localhost 4500
 -1 360 Tampa "BMS,Tampa,27.5521,-82.7407,27.9701,-82.3892," "NOAASensorIDs.txt"
Started Ais Binary Messages Fetcher/Formatterby Alion Science and Technology version 2.0
Parsing command line arguments...
Running FF loop...
Sleep for 0 milliseconds...
Get environmental data from NOAA...
Fetching data from NOAA....
Formatting data...
Processing stations ...
Processing observations ...
Processing Water Level/Met Data Report ...
Processing water level ...
Processing wind data ...
Processing Water Level/Met Data Report ...
Processing water level ...
Processing wind data ...
Processing weather...
Processing Water Level/Met Data Report ...
Processing water level ...
Processing wind data ...
Processing Water Level/Met Data Report ...
Processing wind data ...
Processing Water Level/Met Data Report ...
Processing wind data ...
Processing Water Level/Met Data Report ...
Processing wind data ...
Processing Water Level/Met Data Report ...
Processing current ...
Processing current ...
Processing current ...
Processing current ...
Connecting to QueueManager...
Sending data to QueueManager...
BMS,Tampa,27.5521,-82.7407,27.9701,-82.3892,1,1,0,0,0101101110100001,000100000110001111000000000100100010011110101010110001000000001010110011
0
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1
1010011111111111111110001000000000000000
BMS,Tampa,27.5521,-82.7407,27.9701,-82.3892,3,1,0,0,0101101110100001,000100000110001111000000001100011110010001110001000000010001001110101010
1100010000000110001100110010110100001100 10
BMS,Tampa,27.5521,-82.7407,27.9701,-82.3892,3,0,0,0,0101101110100001,000000000110001111000000001111111111111001001101000111111111111101011
1
1011000001111111111111110001000000000000000
BMS,Tampa,27.5521,-82.7407,27.9701,-82.3892,4,1,0,0,0101101110100001,000100000110001111000000010000010101101110001101100111000101000011101001
1001110001010000011110110011010110010100
BMS,Tampa,27.5521,-82.7407,27.9701,-82.3892,4,0,0,0,0101101110100001,000000000110001111000000010011111111111001001100010000111111111101011
1
1100000011111111111111110001000000000000000
BMS,Tampa,27.5521,-82.7407,27.9701,-82.3892,5,1,0,0,0101101110100001,000100000110001111000000010111101001110110101010110010000000100001010101
0
```

Figure 6. Fetcher/formatter screenshot.

The Fetcher/Formatter operation follows the following steps.

1) Fetcher/Formatter initiates a Web Services connection and data query to the NOAA PORTS server every three minutes (this value is configurable) and retrieves the PORTS data. The NOAA data is updated every 6 minutes on even multiples of 6 minutes.
2) Fetcher/Formatter initiates a Transmission Control Protocol/Internet Protocol (TCP/IP) client socket connection to the Queue Manager (QM) TCP/IP server running on port 4500 and sends out identification sentence: "`FetcherFormatter Tampa`."
3) FF sends the QM the reports (sensor reports, zone reports etc) as binary data as well as some additional tags that describe what type of report it is, the time, the priority, and the area to be transmitted.
4) Fetcher/Formatter sends CSV data sentences containing PORTS Data. Details on the construction and format of these data Sentences can be found in Appendix B.
5) At the end of the transmission, Fetcher/Formatter sends out "`No Data`" and closes the connection.

3.3.2 Queue Manager (QM)

The role of the Queue Manager is to take all of the binary messages as they are generated by the FF and sort them in order of priority/precedence so that the output stream of binary messages is in the desired transmit order. In order to do this message sorting/ prioritization, the QM needs to be given rules on what messages have priority, what the minimum and maximum latencies are, repeat rate, update rate, etc. The output is a sequence of ordered binary messages at a rate that will not overload the AIS channel. In order to do this, the Queue Manager also needs to have feedback on what the current VHF Data Link (VDL) loading is; this information is fed into the QM from IP2Comm software (described below).

Once the Queue Manager is launched, the program starts monitoring on the specified port for incoming clients. The TCP/IP server runs in its own thread, so the user's interface remains responsive at all times. The QM TCP/IP server supports 3 types of clients: Fetcher/Formatter, Ports and Waterways Safety System (PAWSS)/AIS Radio Interface (ARI), and IP2Comm. When a connection is established, the QM outputs on the screen where a connection was established from and what data was sent and received. Figure 7 shows a screen shot of the Queue Manager in operation.

The QM packages AIS messages based on the following configurable parameters:

1) Maximum number of environmental sensor reports to package into a single AIS environmental message (sent as an AIS Binary Message Type 8).
2) Maximum number of AIS messages to transmit per minute.
3) How often to transmit static data (every N minutes).
4) Maximum time to keep dynamic data reports before discarding (in minutes).

The QM uses the following pieces of information for ordering messages:

1) In the queue, keep track of message Time and Type; discard older reports of the same type.
2) Discard expired messages (max time exceeded).
3) Transmit dynamic data every 3 minutes.
4) Transmit static data as per configurable parameter.
5) Transmit dynamic data before static data.
6) Never transmit more messages than specified per configurable parameter (leave them in queue to transmit the next minute).

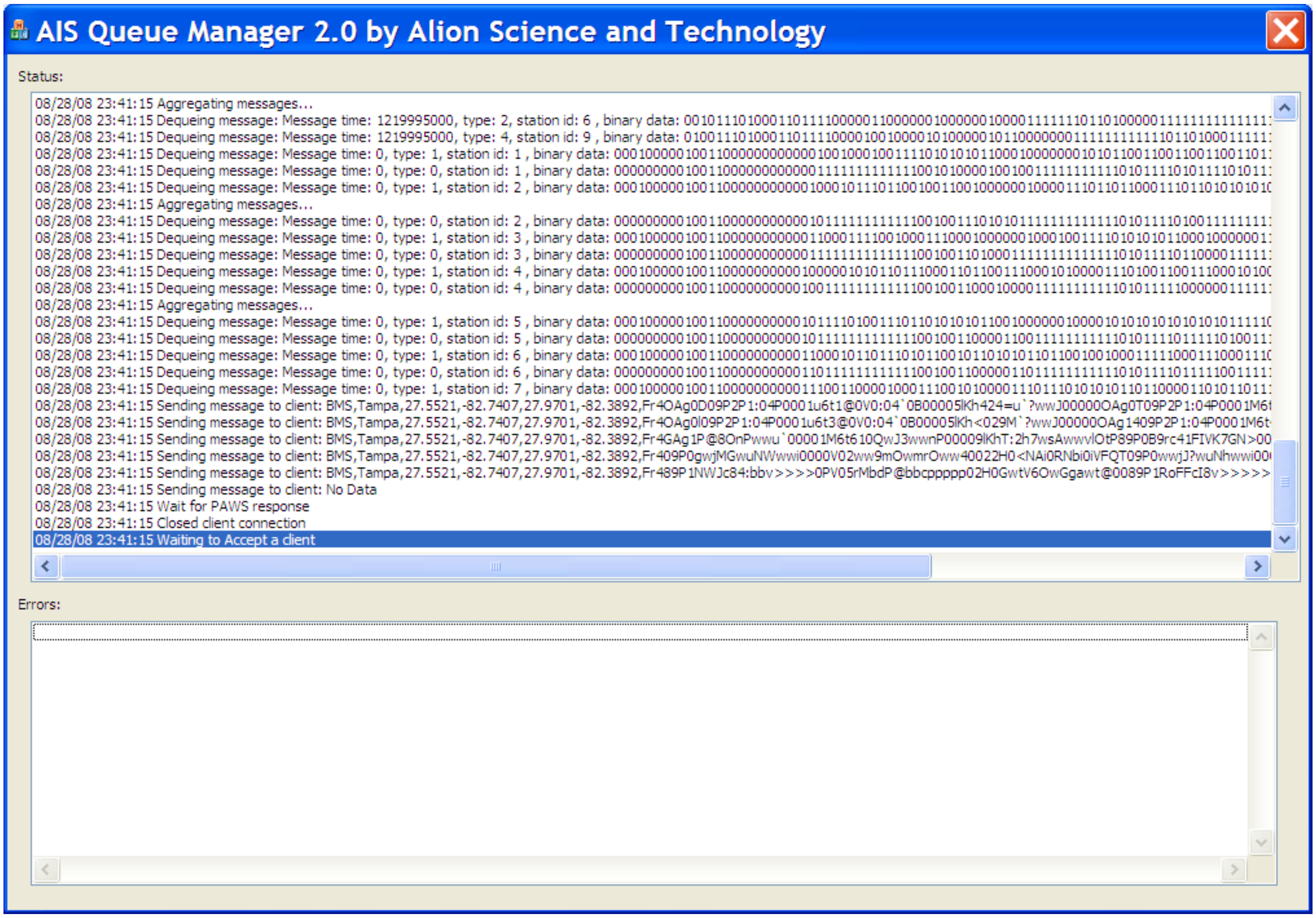

Figure 7. Screen shot of queue manager.

3.3.3 AIS Radio Interface (ARI)

Ports and Waterways Safety System (PAWSS) software is used at most USCG VTSs. This software is used to interface with the AIS base station. Since CVTS Tampa does not run PAWSS software, an additional software component was developed for the test bed. This component is called the AIS Radio Interface and sits between the Queue Manager and the AIS radio and takes the place of PAWSS. As such, it implements the same QM Interface Specification developed for PAWSS to connect to and receive the ordered binary messages. It then provides them directly to the AIS base station radio (using either serial or TCP/IP connections).

The AIS base station radio at CVTS Tampa is an L-3 ProTec base station located at Largo and maintained under contract by L-3 Communications. The radio is accessible via the Internet since the ProTec base station has a Perle Ethernet-to-Serial device built-in to enable network connectivity. Therefore, the AIS Radio Interface software can be run in New London and connect to the AIS base station across the Internet. The ProTec base station supports the IEC 62320-1 AIS Base Station Interface Standard thus standard !xxBBM sentences are used.

The ARI software has the following functionality.

- QM Interface – the software initiates a TCP/IP connection to the QM once a minute and receives messages according to the QM Interface Specification.
- Message Formatting – the software packages AIS Messages from the Queue Manager into NMEA !xxBBM sentences according to NMEA 0183 (IEC 62320-1) specification.
- AIS radio connection – the software initiates a TCP/IP or serial connection to the AIS radio and outputs all formatted NMEA sentences to the AIS radio at once and closes the connection.
- User Interface – program window displays program execution status and errors messages (see Figure 8).
- Configuration file – program run-time parameters such as address of Queue Manager, and AIS Radio address and serial port settings can be changed via configuration file.
- Log File – the software maintains a log file containing: program flow information, messages received from the QM, and messages sent to AIS Radio (as formatted by AIS Radio Interface software).
- Error detection mechanism – the software checks for common errors and upon encountering an error, logs the error into an error log and displays it in a program window. The software can recover from common run-time errors and resume execution.

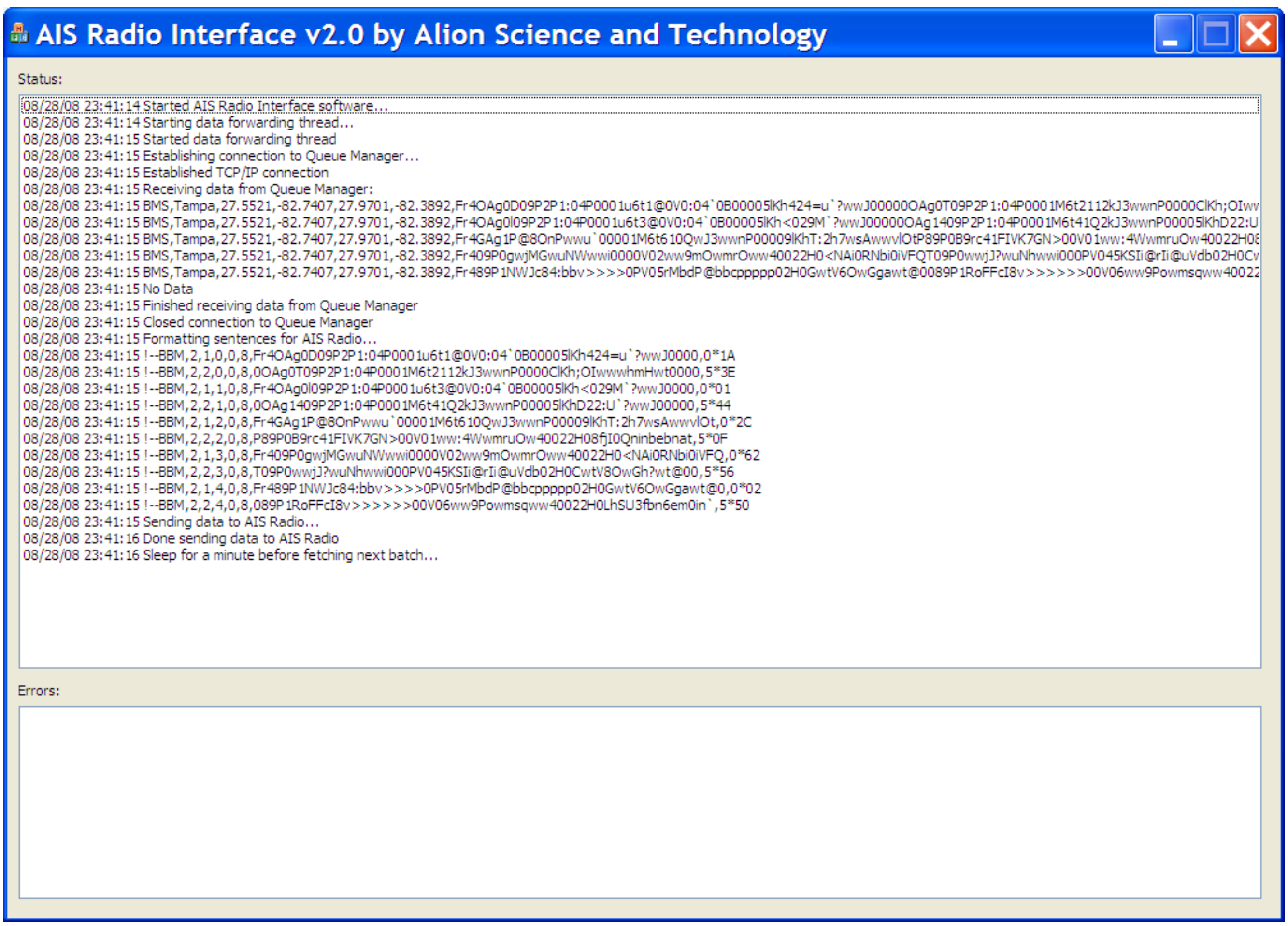

Figure 8. Screen shot of AIS radio interface software.

3.3.4 Internet Protocol - IP2Comm

The current NAIS monitor site at Palmetto uses USCG Research and Development (R&D) Center developed AIS SOURCE software to accept NMEA 0183 (IEC 62320-1) format AIS messages from the AIS receiver and sends the AIS information to servers located at OSC Martinsburg and the R&D Center over the Internet. The R&D Center developed AIS USER software is used to establish a connection to the server to retrieve the data. AIS USER also provides for other processes to get the data from AIS USER via a TCP/IP port. Since the ARINC PPU is designed to accept data via the pilot plug (serial connection) a small piece of Alion developed software, IP2Comm was needed. This software connects to the local TCP/IP port on AIS USER to retrieve the AIS data, strips off the additional information after the NMEA checksum (added by AIS SOURCE), and outputs the data via the computer serial port(s). This serial NMEA 0183 format data is provided to the ARINC PPU for display. In this way VTS operators can monitor AIS binary messages.

Since the IP2Comm software is already parsing all of the AIS messages for serial output, it was decided to implement the VHF Data Link loading estimation here. The VDL loading is determined by calculating the binary data payload of each of the various AIS messages and computing the number of transmission slots-per-minute required to send these messages. The calculated slots-per-minute figure is sent to the Queue Manager software.

The example window (Figure 9) shows the typical information that is displayed when the program is running. All valid NMEA messages are displayed in the application's window. Any invalid messages are also displayed. The program also creates a daily error log such as "`LOG08165.txt.`" The file name is "`LOG`" followed by the two digit year and three digit Julian day. Application start or stop, any invalid NMEA messages, and any serial communications port errors are time-stamped, assigned an error type, and written to the log file.

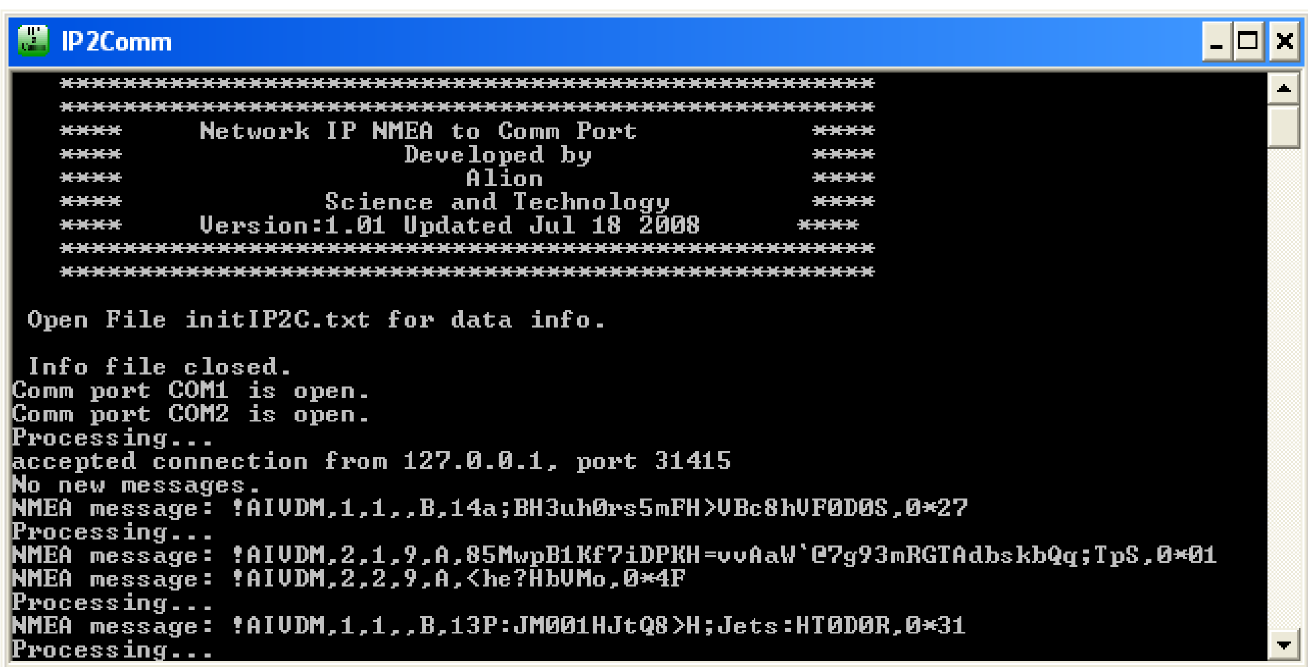

Figure 9. Typical console window for TCP2 serial program.

The IP2Comm software has the following functionality

- A configuration file is used to select the IP address and PORT to connect to (default is 127.00.1 PORT 31414) and to select up to four output serial ports and their baud rates. The configuration file may be edited to change these parameters.
- The IP2Comm software will connect to the TCP/IP address and open the selected serial communication ports. The software will read all NMEA sentences received from the TCP/IP connection, check if valid, and if so, write to the selected serial connections. Extra AIS SOURCE fields after the NMEA checksum are stripped from the message.
- The IP2Comm application will display messages that indicate when an IP address/port connection has been made, when the serial port(s) connections are made, and when valid NMEA messages are transferred.
- A daily error log is generated for invalid NMEA messages with timestamp and any serial communications errors.
- The software also calculates the number of transmission slots per minute required to transmit the NMEA messages from the previous minute. This information is sent to the Queue Manager in the following format: `$AISPM,XXX,MM*CS. Where` "`$AISPM`" is the message header, `XXX` is the integer number of slots per minute, `MM` is an optional monitor identification, and `CS` is the checksum parity. Once a minute, when the number of slots per minute has been determined, the program opens a TCP/IP connection to the Queue Manager software and sends the message.

4 RESULTS TO DATE

The test bed has been in operation for approximately 7 months. During that period there has been some down time due to equipment (i.e. occasional hardware errors, computer lock up, software glitches, and PORTS® sensor network failures) and power outages. These have typically resulted in short amounts of down time, but occasionally data was not available for several days. The plan calls for CVTS Tampa or the Pilots to notify RDC/Alion of any outages in the system. RDC/Alion determines the cause of the outage and corrects the problem as soon as possible depending on the severity. CVTS Tampa equipment has been upgraded and moved to a new location to facilitate implementation of Phase 2 and 3 of the test bed which requires operator interface to create area and waterways management messages.

During the course of the Phase I trial, data was recorded both manually and automatically. The pilots were asked to log feedback (discussed in the next section) manually after each transit. Data has been recorded continuously at each of the software processes: Fetcher/Formatter, Queue Manager, and IP2Comm enabling post-analysis to be done on the messages sent.

4.1 Pilot Feedback

Feedback has been collected continuously from the pilots during Phase I. They were provided with a log sheet (see Appendix C) and asked to fill it out after each transit and then FAX the sheets back to RDC/Alion. Nine pilots have filled out log sheets for transits between 10/9/08 and 3/12/09. These log sheets have been compiled into a spreadsheet for analysis. To date 165 transits have been recorded; 35 of these or 21 percent reported that the AIS data was not always available; 62 or 38 percent reported noticeable latency. Almost all of the transits indicated that AIS binary broadcast is the preferred means of receiving the PORTS data and also that the pilots preferred the text display of the data over a graphical display.

Additional feedback from the pilots was gathered during an onsite meeting on 22 April 2009. At this meeting the latency issue was discussed. Currently, due to the way in which NOAA manages the data, there is about 12 minutes of latency in the data when it is obtained from the database. The AIS transmit process adds perhaps a minute to this. The pilots were asked to report if longer latencies were observed which would indicate problems with the systems or with the AIS reception onboard the ship. The data not available issue was also discussed and since the problems experienced to date (described above) should not repeat, the pilots were asked to log data outages and notify RDC so that it can be investigated and corrected quickly. Some outages are due to faulty AIS installations on the vessels the pilots are riding. In Phase II, some CG vessels with constant, known, AIS installations will be used as test platforms to provide a baseline of performance.

The pilots were also asked to complete a short questionnaire which was handed out at the meeting. Seven pilots turned in the forms; all but one were uniformly pleased with the system. The remaining pilot had a software installation problem that needs to be resolved.

4.2 VDL Loading – Messages/Slots

One central AIS issue is the impact of using binary messages on the VDL loading. The AIS VDL is composed of a finite number of slots that are reserved by users. There is a concern that these slots can be fully utilized in heavy traffic situations in which case the addition of binary messages would negatively impact the overburdened capacity. The loading in Tampa is very low; out of the maximum of 4,500 slots/minute available the typical loading is 200-300 slots per minute (monitored at Palmetto receive site). The test bed generates about 5-6 slots/minute of traffic or equivalent to adding one additional Class A equipped vessel to the harbor; so the loading has not been an issue to date. As additional binary messages are added in Phases II and III, and as more and more Class B devices are used, VDL loading will be investigated further.

Another related question that has been raised is whether the one-slot environmental binary messages actually fit into a single slot. AIS messages have a start and an end flag that consists of the binary sequence 01111110. To ensure that data is not mistaken for a start or end flag the data must not have any sequence of binary 1's longer than five. During transmission, bit stuffing is used to maintain this message integrity; if more than five consecutive ones are found in the data, a binary 0 is inserted after the five 1's (this process is reversed at the receiver). This will affect the length of the message and some messages that require only one time slot with no "bit stuffing" may require more than one time slot if too much bit stuffing is needed. The standard AIS message format allows for 4 bit stuffs; any more than that and the length of the binary message may exceed 1 slot[2].

Typical AIS messages were collected over several days and analyzed to calculate how many bit stuffs were required to transmit each message. This was calculated by analyzing each received message on a binary basis and counting the number of sequences of five 1's. Since we were interested in comparing the single-slot performance of the environmental message to that of existing single-slot messages we only parsed single-slot messages (which leaves out message types 5, 19 and 21 and multi-slot versions of message types 6, 12, 14, 17, and 26). During the 9 day period, there were no messages of types 2, 5, 19, 21, 22, and 23. Many of the other message types (6-14, 16, 17, 20, 25, 26) occurred very infrequently (see Figure 10 for a distribution of message types). Interestingly, there were also some message types 27-31 received even

[2] Since the message format also has extra bits to allow for propagation time it is difficult to determine for sure if a 1 slot time is exceeded.

though these are NOT defined in ITU Rec M.1371[5]. Some statistics for the message types that occurred most frequently are listed in Table 4. This data is then plotted in Figure 11. The same data is plotted as a cumulative distribution in Figure 12. It is clear from Figure 12 that a significant number of the environmental messages may be exceeding 1 slot – only 40 percent have 4 or less bit stuffs. As a comparison 70 percent of the message type 1's have 4 or less bit stuffs. Upon examining Figure 11, there are sizeable percentages of the environmental messages that have 5 or 8 bit stuffs. It may be helpful to reexamine the environmental message coding to try to eliminate some of the bit stuffs.

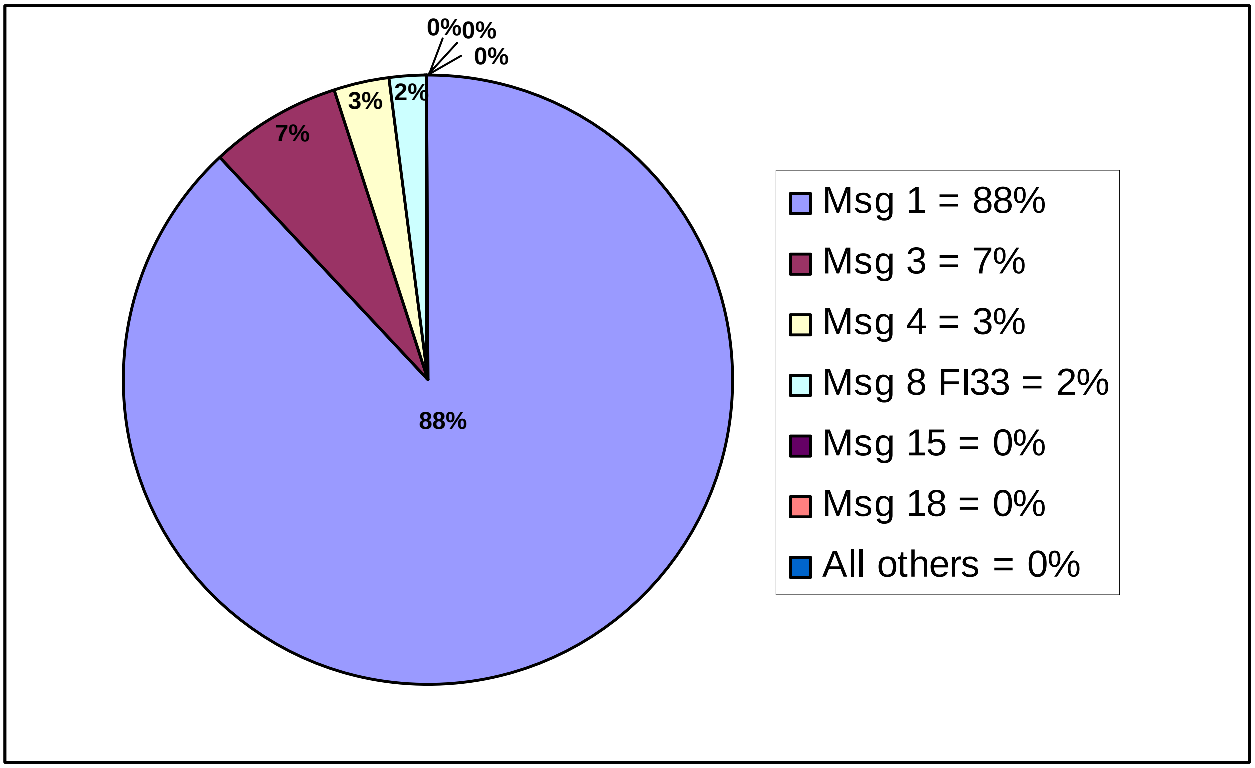

Figure 10. Message distribution.

Table 4. Statistics for the most common message types.

		Percentage of Total Messages at Each Number of bit stuffs											
Msg Type	**Total Msgs**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Msg 1	2206508	0.6	10.9	16.8	22.4	20.9	16.5	6.7	3.7	1.3	0.2	0.0	0.0
Msg 3	182221	0.1	14.1	30.2	31.7	16.6	5.7	1.3	0.2	0.0	0.0	0.0	0.0
Msg 4	69354	0.0	0.0	0.0	0.0	62.7	31.3	5.4	0.5	0.0	0.0	0.0	0.0
Msg 8 FI 33	57610	0.0	0.0	32.3	3.5	1.0	34.1	10.1	2.1	13.6	3.1	0.2	0.0
Msg 18	1357	0.0	0.0	14.0	46.3	28.6	9.4	1.6	0.1	0.0	0.0	0.0	0.0
Msg 15	763	56.4	30.3	12.3	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
All others	484												

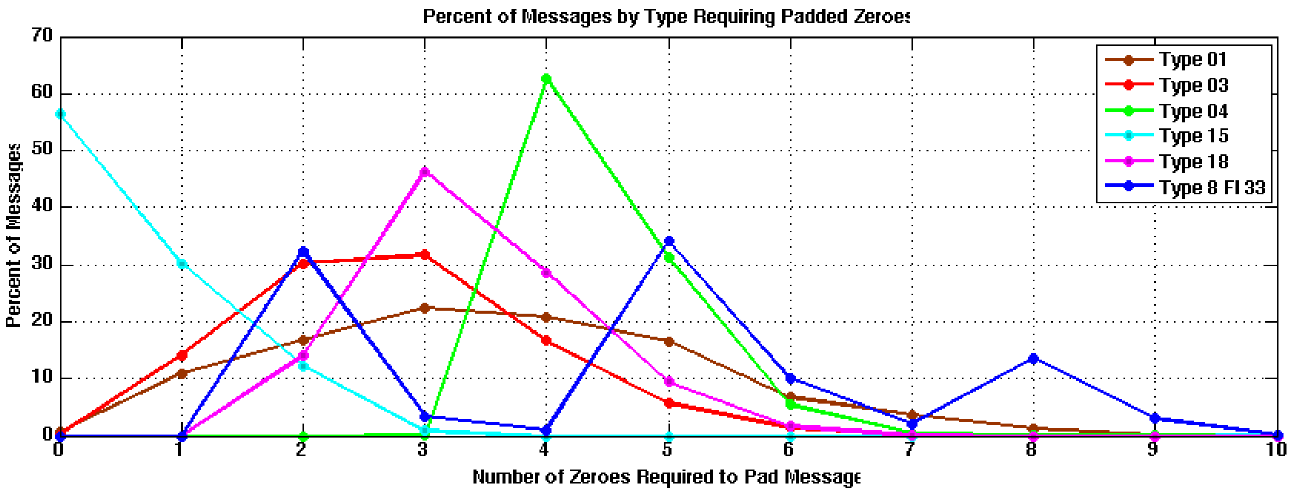

Figure 11. Percent of messages by type needing various numbers of bit stuffs.

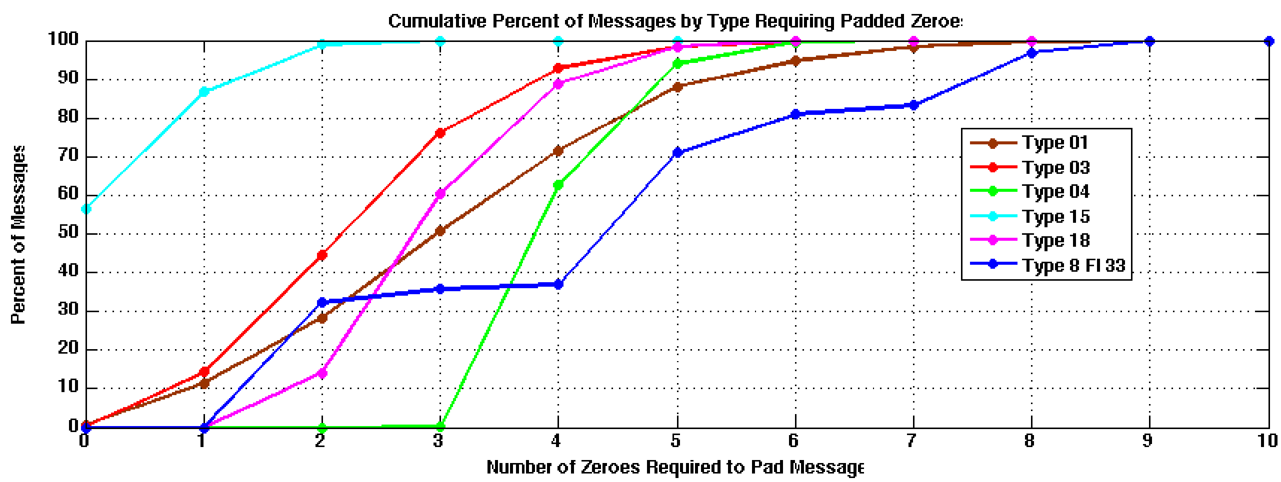

Figure 12. Cumulative percent of messages by type at each increasing number of bit stuffs.

5 KEYS TO BINARY MESSAGING

5.1 Lessons Learned

Some of the key lessons learned to date from the test bed relate to defining what is needed in order to implement binary messaging. The following are the steps needed.

1) Define the message format to meet the information requirements. The "payload" needs to be defined and standardized so software will understand the message. This is being worked on for the test bed applications by the RTCM SC121 working group and the IMO Correspondence Group on AIS Binary Messages.
2) Create the Message. This could be auto-created from database information (e.g. NOAA PORTS®) or it could be user-created (zones, ordering, etc). In either case the data then gets put into the binary "payload." This is done by the *Fetcher/Formatter* and *VTS Info Manager* in the Tampa Test Bed.

3) Route the Message. This involved getting the message to the correct transmitter. This is the responsibility of the *Queue Manager* and *AIS Radio Interface* in the Tampa Test Bed. For this to happen, there are numerous issues to be managed:

   a. Queue process
   b. Rule-based prioritization
   c. Routing to correct transmitter according to area (auto or user-specified)
   d. VDL loading monitoring
   e. Message format (binary for transmission, NMEA/IEC for radio interface, undefined for terrestrial network routing)

Table 5 summarizes some of the operational implementation issues that need to be addressed in moving from a test bed to an operational implementation.

Table 5. Test bed to operational system implementation issues.

Issue	Operational	Test bed
Passing of Transmit information on shore side prior to transmit	Versioning, security, validations, authentication	Comma-separated values
Routing	System decides, operator decides	Operator decides and PAWSS selects base station/s to transmit
Addressed vs Broadcast	Need to decide which to use	Presently only doing broadcast
VDL Loading	How many slots to use, which base stations to transmit, if loading high binary dropped, how does operator know	Queue manager monitors VDL loading, drops messages and reprioritizes as necessary
Log files for data output by shore components	Each node? Use database	Log files – Input from NOAA, output from Formatter, output from queue manager
Operator notification	Response back network path that message was transmitted, cross check with NAIS receive sites source data, Message corrupted, VDL loading dropped message, notify operator for action	TV32 displays transmitted messages to operator. If message dropped or corrupted operator will not see message displayed

5.2 Conclusions and Recommendations

CVTS Tampa has provided a good development environment for testing AIS binary messages. The environmental message proved to be a good first choice since it is automated and does not require any operator interaction to broadcast the message. This allowed all the software and interfaces to be developed and a user group to receive data without significant training or modifications to procedures at the CVTS.

The Tampa Bay Pilots and CVTS (USCG and Port Authority) have been very supportive and enthusiastic partners. The test bed is able to create and deliver binary message which mariners can use aboard ship. Pilots preferred receiving the PORTS® data through the AIS broadcast vs. phone or internet. Pilots also preferred the text display of the data over a graphical display.

Broadcasting PORTS data (10 sensors) via AIS every three minutes has very minimal impact to the VDL. It is equivalent to adding one vessel equipped with AIS to the VDL. It is clear that a significant number of the environmental messages being transmitted in Tampa may be exceeding 1 slot – a sizeable percentage of the environmental messages (~60 percent) are exceeding the 4 or less bit stuffs which guarantees a single slot transmission. We will reexamine the environmental message coding to try to eliminate some of the bit stuffs. We will also use this information to better estimate slot reservations needed to be made by the base station for transmitting binary messages. As we begin Phase 2 and 3, those messages will also be examined for better slot size determination.

As we proceed with Phase 2 and 3 of this test bed, the Sector Command Center Operator and VTS Operator will be more involved with the creation of the messages to be broadcast. These messages will communicate dynamic information concerning a specified geographic area, line or point. The information will convey pertinent time-critical navigation safety information to mariners. Training on the Graphical User Interface to create the messages and determination of which messages to broadcast via AIS will be necessary.

It is highly recommended that this work be incorporated into NAIS Increment 2 development.

6 REFERENCES

[1] G. W. Johnson, *AIS Transmit Capability: Summary Report on Proposed Designs for Test Bed System*, Deliverable Two under DO HSCG32-07-F-R00021 on contract GS-23F-0291P, prepared for the USCG R&D Center, Groton, CT, 2008.

[2] G. W. Johnson, *Automatic Identification System Transmit: Implementation Plan* Deliverable Seven under DO HSCG32-07-F-R00021 on contract GS-23F-0291P, prepared for the USCG R&D Center, Groton, CT, 2008.

[3] G. W. Johnson, L. Alexander, I. M. Gonin *et al.*, *Automatic Identification System Transmit: Functional Requirements Study*, R&DC UDI # 978, U.S. Coast Guard R&D Center, Groton, CT, 2008.

[4] *Guidance on the Application of AIS Binary Messages*, SN/Circ. 236, IMO, Maritime Safety Committee, London, 2004.

[5] *Technical Characteristics for an Automatic Identification System using Time Division Multiple Access in the VHF Maritime Mobile Band*, ITU-R M.1371-3, International Telecommunications Union, 2007.

APPENDIX A. ENVIRONMENTAL MESSAGE

A.1 Environmental Message

As per ITU-1371 series a binary message consist of three parts:

1) Standard AIS framework (message ID, repeat indicator, source ID, and, for addressed binary messages, a destination ID)
2) 16-bit application identifier (AI = DAC + FI), consisting of:

    a. 10-bit designated area code (DAC) – based on the MID, as maintained in ITU Radio Regulations, Appendix 43, table 1. DAC assignments are: International (DAC = 1), maintained by international agreement for global use; regional (DAC > 1), maintained by the regional authorities affected; and test (DAC = 0), used for test purposes. It is the intention that any application specific message can be utilized worldwide. The choice of the DAC does not limit the area where the message can be used.
    b. 6-bit function identifier (FI) – allows for 64 unique application specific messages.

3) Data content (variable length up to a given maximum)

A new binary message for transmitting environmental information has been developed and is described in Table A-1. In order to maximize flexibility the message has been designed to carry from 1 to 8 sensor reports (a message with 1 sensor report can be sent in 1 slot, a message with 8 sensor reports takes 5 slots). Each sensor report carries the dynamic or static information relating to a specific sensor.

Table A-1. Environmental binary message framework.

Parameter		Number of Bits	Description
Standard Message Header	Message ID	6	Identifier for Message 8; **Set to 8** (broadcast, no acknowledgement)
Standard Message Header	Repeat Indicator	2	Used by the repeater to indicate how many times a message has been repeated. See § 4.6.1, Annex 2; 0-3; 0 = default; 3 = do not repeat any more. **Set to 0 (default)**
Standard Message Header	Source MMSI	30	MMSI number of source station. Varies according to the transmitter ID.
Standard Message Header	Spare	2	Not used. **Set to zero**
Binary Data	Designated Area Code	10	Designated area code (DAC). This code is based on the maritime identification digits (MID). Exceptions are 0 (test) and 1 (international). Although the length is 10 bits, the DAC codes equal to or above 1000 are reserved for future use. **Set to 366 (US)**
Binary Data	Function Identifier	6	Function identifier. The meaning should be determined by the authority which is responsible for the area given in the designated area code. **Set to 33**
Binary Data	Application Data	Max 952	From 1 to 8 sensor reports, each structured as in Section 1.1. Total number of reports is determined by the receiver based on the length of data.
	Total number of bits	Max 1008	= 56 + N*112 N Total Bits Slots Required (168 bits in first 210 in 2-5) 1 168 bits 1 2 280 bits 2 (max 378) 3 392 bits 3 (max 588) 4 504 bits 3 5 616 bits 4 (max 798) 6 728 bits 4 7 840 bits 5 (max 1008) 8 952 bits 5

A.2 Common to all Report Types

Each Environmental Message has 56 bits of standard header. This leaves 112 bits for payload. Each sensor report has 27 bits of common data leaving 85 bits for sensor data. The framework for the sensor report is in Table A-2.

Table A-2. Environmental message sensor report framework.

Parameter	Number of Bits	Description
Report Type	4	Environmental Report Type as per Section 1.1.1
Timestamp	16	This is the date and time of the data. Just Day, hours, and minutes into the day – minute resolution – UTC. UTC day (5 bits):1-31; 0 = UTC day not available = default. UTC hour (5 bits): 0-23; 24 = UTC hour not available = default; (25-31 = Reserved for future use). UTC minute (6 bits): 0-59; 60 = UTC minute not available = default; (61-63 = Reserved for future use).
Sensor ID	7	Binary identifier of sensor – combined with transmitter MMSI to fully ID sensor.
Sensor Data	Max of 85	Remaining 85 bits are according to the sensor type – see Sections 1.2.1 through 1.2.x.
Total number of bits	Max of 112	

A.2.1 Environmental Message Sensor Report Type (4 bits)

There are a variety of sensor types that can be transmitted using this message. 4 bits gives 16 possible values, the number is the item from Table A-3.

Table A-3. Environmental message sensor report types.

Value	Description
0	Site Location
1	Station ID
2	Wind
3	Water level
4	Current Flow Report v1
5	Current Flow Report v2
6	Horizontal Current Flow Current
7	Sea state
8	Salinity
9	Weather
10	Air gap / Air draft
11	Reserved for future use
12	Reserved for future use
13	Reserved for future use
14	Reserved for future use
15	Reserved for future use

A.3 Sensor Data

Details for the 85 bits of information for each sensor report type are detailed in these sections. All possibilities for each data field are described. In each case Sensor Unavailable means that the specific reading is not ever possible from that sensor location. Data Unavailable means that the reading is possible but is not available for the current report (sensor could be malfunctioning).

A.3.1 Site Location

Table A-4. Site location.

Parameter	Number of Bits	Description
Longitude	28	Longitude in 1/10 000 minute. (±180°, East = positive (as per 2's complement), West = negative (as per 2's complement); 181° (6791AC0h) = not available = default)
Latitude	27	Latitude in 1/10 000 minute. (±90°, North = positive (as per 2's complement), South = negative (as per 2's complement); 91° (3412140h) = not available = default)
Altitude	11	Altitude of the sensor relative to MSL in 0.1m resolution. 0.0 – 204.5m, 204.6 = altitude>204.5m, 204.7 = Data unavailable = default.
Sensor Owner	4	Owner of the sensor / responsible for the sensor data 0 = U.S. Coast Guard 1 = U.S. NOAA 2 = U.S. Army Corps of Engineers 15 = unknown (3 – 14 = Reserved for future use)
Data Timeout	3	Length of time that data is valid – do not use data after this timeout period. 0 = never = default, 1 = 10 min, 2 = 1 hr, 3 = 6 hrs, 4 = 12 hrs, 5 = 24 hrs, (6 – 7 = Reserved for future use).
Spare	12	Set to zero. Reserved for future use.
Total # of bits	85	

A.3.2 Station ID

Table A-5. Station ID.

Parameter	Number of Bits	Description
Name	84	Fourteen 6-bit ASCII characters = Agency reference number. 6 bit ASCII characters as per Table 44 in ITU 1371-3.
Spare	1	Set to zero. Reserved for future use.
Total # of bits	85	

A.3.3 Wind Report

Table A-6. Wind report.

Parameter	Number of Bits	Description
Wind Speed	7	Average of wind speed values over the last 10 min. in 1 knot increments. 0-125 kts, 126 = wind>125kts, 127 = Data unavailable = default.
Wind Gust	7	Max wind speed reading during the last 10 min. in 1 knot increments. 0-125 kts, 126 = wind>125kts, 127 = Data unavailable = default.
Wind Direction	9	Direction of the average wind over the last 10 minutes in 1 degree increment. 0 – 359 degrees, 360 = Data unavailable = default, (361-511 = reserved for future use).
Wind Gust Direction	9	Direction of the max wind over the last 10 minutes in 1 degree increment. 0 – 359 degrees, 360 = Data unavailable = default, (361-511 = reserved for future use).
Sensor Data Description	3	Indication of data. 0 = no data = default, 1 = real time with Quality Control, 2 = raw real time, 3 = predicted, 4= nowcast,7 = Sensor unavailable. (5-6 = reserved for future use).
Forecast Wind Speed	7	Predicted average wind speed in 1 knot increment. 0-125 kts, 126 = wind>125kts, 127 = Forecast unavailable =default.
Forecast Wind Gust	7	Predicted maximum wind speed in 1 knot increment. 0-125 kts, 126 = wind>125kts, 127 = Forecast unavailable =default.
Forecast Wind Forecast Direction	9	Predicted direction of the average wind in 1 degree increment. 0 – 359 degrees, 360 = Forecast unavailable = default, (361-511 = reserved for future use).
Valid Time of Forecast	16	This is the date and time for the forecast. Minute resolution. UTC day: 1-31; 0 = UTC day not available = default (5 bits). UTC hour: 0-23; 24 = UTC hour not available = default, (25-31 = reserved for future use) (5 bits). UTC minute: 0-59; 60 = UTC minute not available = default, (61-63 = reserved for future use) (6 bits).
Duration	8	Duration of validity of the forecast from the time of the forecast, minute resolution. 1-255 minutes, 0 = cancel forecast.
Spare	3	Set to 0. Reserved for future use.
Total # of bits	85	

A.3.4 Water level Report

Table A-7. Water level report.

Parameter	Number of Bits	Description
Water Level Type	1	Type of water level; 0 or 1. 0 = Relative to reference datum, 1 = Water depth.
Water Level	16	Water level in centimeters; range of -327.67 to +327.67 meters. -32767 = -327.67 m or less, +32767 = +327.67 m or greater, -32768 = data unavailable = default.
Trend	2	0 = increasing 1 = decreasing 2 = steady 3= unknown VERIFY NUMBERS WITH DARREN WRIGHT
Reference Datum	5	Defines datum used. 0: MLLW 1: IGLD-85 2: Water Depth 3: STND 4: MHHW 5: MHW 6: MSL 7: MLW 8: NGVD 9: NAVD 10: WGS-84 11: LAT 12: Pool 13: Gauge 14: Local river datum 31: Unknown/Unavailable = default. (15-30 = Reserved for future use)
Sensor Data Description	3	Indication of data. 0 = no data = default, 1 = real time with Quality Control, 2 = raw real time, 3 = predicted, 4= nowcast,7 = Sensor unavailable. (5-6 = reserved for future use).
Forecast Water Level Type	1	Type of water level for forecast; 0 or 1. 0 = Relative to reference datum, 1 = Water depth.
Forecast Water Level	16	Forecast water level in centimeters; range of -327.67 to +327.67 meters. -32767 = -327.67 m or less, +32767 = +327.67 m or greater,-32768 = Forecast unavailable = default.
Valid Time of Forecast	16	This is the date and time for the forecast. Minute resolution. UTC day: 1-31; 0 = UTC day not available = default (5 bits). UTC hour: 0-23; 24 = UTC hour not available = default, (25-31 = reserved for future use) (5 bits). UTC minute: 0-59; 60 = UTC minute not available = default, (61-63 = reserved for future use) (6 bits).
Duration	8	Duration of validity of the forecast from the time of the forecast. Minutes, 1-255 minutes, 0 = cancel forecast.
Spare	17	Set to 0, reserved for future use.
Total # of bits	85	

A.3.5 Current Flow Report version 1

Table A-8. Current flow report version 1.

Parameter	Number of Bits	Description
Current speed 1	8	Speed of current 1 measured at a chosen level below the sea surface in 0.1 knot increments. 0.0 – 25.0 knots, 25.1 = speed > 25 knots, 25.5 = Data unavailable = default. (25.2-25.4 = Reserved for future use).
Current direction 1	9	Direction of current 1 in 1 degree increment. 0 – 359 degrees, 360 = Data unavailable = default, (361-511 = Reserved for future use).
Current measuring level 1	9	Measurement level of current 1 below sea surface in 1 m increments. 0 – 360 m,511 = Data unavailable = default. NOTE – check on 360m requirement with NDBC. If don't need can go to 60m depth and drop to 6 bits. (361-510 = Reserved for future use).
Current speed 2	8	Speed of current 2 measured at a chosen level below the sea surface in 0.1 knot increments. Same as current speed 1.
Current direction 2	9	Direction of current 2 in 1 degree increment. Same as current direction 1.
Current measuring level 2	9	Measurement level of current 2 in meters below sea surface in 1 m increments. Same as current measuring level 1.
Current speed 3	8	Speed of current 3 measured at a chosen level below the sea surface in 0.1 knot increments. Same as current speed 1.
Current direction 3	9	Direction of current 3 in 1 degree increment. Same as current direction 1.
Current measuring level 3	9	Measurement level of current 3 in meters below sea surface in 1 m increments. Same as current measuring level 1.
Sensor Data Description	3	Indication of data. 0 = no data = default, 1 = real time with Quality Control, 2 = raw real time, 3 = predicted, 4= nowcast,7 = Sensor unavailable. (5-6 = reserved for future use).
Spare	4	Set to 0, reserved for future use.
Total # of bits	85	

A.3.6 Current Flow Report version 2

Table A-9. Current flow report version 2.

Parameter	Number of Bits	Description
Current vector component North (u) 1	8	Speed of North component of current 1 measured at a chosen level below the sea surface in 0.1 knot increments. 0.0 – 25.0 knots, 25.1 = speed > 25 knots, 25.5 = data unavailable = default. (25.2-25.4 = Reserved for future use).
Current vector component East (v) 1	8	Speed of East component of current 1 measured at a chosen level below the sea surface in 0.1 knot increments. 0.0 – 25.0 knots, 25.1 = speed > 25 knots, 25.5 = data unavailable = default. (25.2-25.4 = Reserved for future use).
Current vector component Up (z) 1	9	Speed of Up component of current 1 measured at a chosen level below the sea surface in 0.1 knot increments. 0.0 – 25.0 knots, 25.1 = speed > 25 knots, 25.5 = data unavailable = default. (25.2-25.4 = Reserved for future use).
Current measuring level 1	9	Measurement level of current 1 in meters below sea surface in 1 m increments. 0 – 360m, 511 = data unavailable = default. (361-510 = Reserved for future use).
Current vector component North (u) 2	8	Speed of North component of current 2 measured at a chosen level below the sea surface in 0.1 knot increments. Same as for current 1.
Current vector component East (v) 2	8	Speed of East component of current 2 measured at a chosen level below the sea surface in 0.1 knot increments. Same as for current 1.
Current vector component Up (z) 2	9	Speed of Up component of current 2 measured at a chosen level below the sea surface in 0.1 knot increments. Same as for current1.
Current measuring level 2	9	Measurement level of current 2 in meters below sea surface in 1 m increments. Same as for current 1.
Sensor Data Description	3	Indication of data. 0 = no data = default, 1 = real time with Quality Control, 2 = raw real time, 3 = predicted, 4= nowcast,7 = Sensor unavailable. (5-6 = reserved for future use).
Spare	14	Set to 0, reserved for future use.
Total # of bits	85	

A.3.7 Horizontal Current Flow Report

Table A-10. Horizontal current flow report.

Parameter	Number of Bits	Description
Current Reading 1 Bearing	9	Bearing of current 1 reading from sensor position, 1 degree resolution. 0 – 359 degrees, 360 = Data unavailable = default, 511 = Sensor unavailable. (361-510 = Reserved for future use).
Current Reading 1 Distance	7	Distance of current 1 reading from sensor position, 1m resolution. 0 – 125m, 127 = data unavailable = default, (126 = Reserved for future use).
Current 1 speed	8	Speed of current 1 measured at a chosen level below the sea surface in 0.1 knot increments. 0.0 – 25.0 knots, 251 = speed > 25 knots, 255 = data unavailable = default. (252-254 = Reserved for future use).
Current 1 direction	9	Direction of current 1 in 1 degree increment. 0 – 359 degrees, 360 = data unavailable = default, (361-511 = Reserved for future use).
Current 1 measuring level	9	Measurement level of current 1 in meters below sea surface in 1 m increments. 0 – 360m, 511 = data unavailable = default, (361-510 = Reserved for future use).
Current Reading 2 Bearing	9	Bearing of current 2 reading from sensor position, 1 degree resolution. Same as for current 1 bearing.
Current Reading 2 Distance	7	Distance of current 2 reading from sensor position, 1m resolution. Same as for current 1 distance.
Current 2 speed	8	Speed of current 2 measured at a chosen level below the sea surface in 0.1 knot increments. Same as for current 1 speed.
Current 2 direction	9	Direction of current 2 in 1 degree increment. Same as for current 1 direction.
Current 2 measuring level	9	Measurement level of current 1 in meters below sea surface in 1 m increments. Same as for current 1 level.
Spare	1	Set to 0, reserved for future use.
Total # of bits	85	

A.3.8 Sea State Report

Table A-11. Sea state report.

Parameter	Number of Bits	Description
Swell height	8	Height of the swell, 0.1 m resolution. 0.0 – 25.0 m, 25.1 = height > 25 m, 255 = data unavailable = default (252 - 254 = Reserve for future use).
Swell period	6	Swell period in seconds, 1 s resolution. 0 – 60 s, 63 = data unavailable = default; (61 - 62 = Reserved for future use).
Swell direction	9	Direction of swells, 1 degree resolution. 0 – 359 degrees, 360 = data unavailable = default, (361-511 = Reserved for future use).
Sea state	4	According to Beaufort scale (manual input?). An alternative is the WMO Sea State scale. Question – should we switch to this? **Beaufort** **Scale Sea Conditions** 0 Flat. 1 Ripples without crests. 2 Small wavelets. Crests of glassy appearance, not breaking 3 Large wavelets. Crests begin to break; scattered whitecaps 4 Small waves. 5 Moderate (1.2 m) longer waves. Some foam and spray. 6 Large waves with foam crests and some spray. 7 Sea heaps up and foam begins to streak. 8 Moderately high waves with breaking crests forming spindrift. Streaks of foam. 9 High waves (6-7 m) with dense foam. Wave crests start to roll over. Considerable spray. 10 Very high waves. The sea surface is white and there is considerable tumbling. Visibility is reduced. 11 Exceptionally high waves. 12 Huge waves. Air filled with foam and spray. Sea completely white with driving spray. Visibility greatly reduced. 15 = data unavailable = default, (13-14 = Reserved for future use).
Sensor Data Description	3	Indication of data for swells. 0 = no data = default, 1 = real time with Quality Control, 2 = raw real time, 3 = predicted, 4= nowcast,7 = Sensor unavailable. (5-6 = reserved for future use).

Table A-11. Sea state report (Continued).

Parameter	Number of Bits	Description
Water temperature	10	Temperature of the water in degrees C, 0.1 degree resolution. -10.0 to + 50.0 degrees, Temp = Decimal value /10 – 10 for Decimal = 0-600 601 = data unavailable = default. (602 – 1023 = Reserved for future use).
Water temperature depth	7	Depth of water temperature sensor, 0.1m resolution. 0-12m, 12.7 = data unavailable = default; (121 -126 = Reserved for future use).
Sensor Data Description	3	Indication of data for temperature. 0 = no data = default, 1 = real time with Quality Control, 2 = raw real time, 3 = predicted, 4= nowcast,7 = Sensor unavailable. (5-6 = reserved for future use).
Significant wave height	8	Height of the waves, 0.1 m resolution. 0.0 – 25.0 m, 25.1 = height > 25 m 255 = data unavailable = default; (252 - 254 = Reserved for future use).
Wave period	6	Wave period, 1 s resolution. 0 – 60 s, 63 = data unavailable = default; (61-62 = Reserved for future use).
Wave direction	9	Direction of waves, 1 degree resolution. 0 – 359 degrees, 360 = data unavailable = default, (361-511 = Reserved for future use).
Sensor Data Description	3	Indication of data for waves. 0 = no data = default, 1 = real time with Quality Control, 2 = raw real time, 3 = predicted, 4= nowcast,7 = Sensor unavailable. (5-6 = reserved for future use).
Salinity	9	Salinity in 0.1‰ (ppt) increments. 0.0 – 50.0 ‰, 50.1 = salinity greater than 50.0, 510 = data unavailable = default, 511 = sensor unavailable; (502 - 509 = Reserved for future use).
Total number of bits	85	

A.3.9 Salinity Report

Table A-12. Salinity report.

Parameter	Number of Bits	Description
Water temperature	10	Temperature of water in degrees Celsius, 0.1 degree resolution.-10.0 to + 50.0 degrees Temp = Decimal value /10 – 10 for Decimal = 0-600, 1022 = data unavailable, 1023 = sensor unavailable = default, (601 – 1021 = Reserved for future use).
Conductivity	10	Water conductivity in Siemens/meter, resolution of 0.01 S/m. 0.0 - 7.00 Siemens/meter, 7.01 = conductivity > 7.00 1022 = data unavailable, 1023 = sensor unavailable = default, (702 - 1021 = Reserved for future use).
Water pressure	16	Pressure of water in decibars, resolution of 0.1 decibars. 0.0 to 6000.0, 6000.1 = pressure > 6000.1, 65534 = data unavailable, 65535 = sensor unavailable = default, (60002 – 65533 = Reserved for future use).
Salinity	9	Salinity in 0.1‰ (ppt) increments. 0.0 – 50.0 ‰, 50.1 = salinity greater than 50.0, 510 = data unavailable = default, 511 = sensor unavailable; (502 - 509 = Reserved for future use).
Salinity type	2	0 = measured 1 = calculated using PSS-78 2 = calculated using other method 3 = Reserved for future use
Sensor Data Description	3	Indication of data for salinity. 0 = no data = default, 1 = real time with Quality Control, 2 = raw real time, 3 = predicted, 4= nowcast,7 = Sensor unavailable. (5-6 = reserved for future use).
Spare	17	Set to 0, reserved for future use.
Total # of bits	85	

A.3.10 Weather Report

Table A-13. Weather report.

Parameter	Number of Bits	Description
Air temperature	11	Dry bulb temperature in degrees Celsius, 0.1 degree resolution, -60.0 to +60.0 degrees Celsius, -1024 = Data unavailable = default. (-1023 thru -601 = Reserved for future use), (601 – 1023 = Reserved for future use).
Sensor Data Description	3	Indication of data for air temperature. 0 = no data = default, 1 = real time with Quality Control, 2 = raw real time, 3 = predicted, 4= nowcast,7 = Sensor unavailable. (5-6 = reserved for future use).
Precipitation (type)	2	According to WMO 0=Rain, 1=Snow, 2=Rain and snow, 3=other
Horizontal visibility	8	Visibility in Nautical Miles, 0.1 NM resolution. 0.0 – 25.0 NM, 25.1 = visibility > 25NM, 254 = data unavailable, 255 = sensor unavailable = default, (252 - 253 = Reserved for future use).
Dew point	10	Dew point temperature in degrees Celsius, 0.1 degree resolution, -20.0 - +50.0 degrees. Temp = Decimal value /10 – 20 for Decimal = 0-700, 1023 = data unavailable, (701 – 1022 = Reserved for future use).
Sensor Data Description	3	Indication of data for dewpoint. 0 = no data = default, 1 = real time with Quality Control, 2 = raw real time, 3 = predicted, 4= nowcast,7 = Sensor unavailable. (5-6 = reserved for future use).
Air pressure	9	Air pressure, defined as pressure reduced to sea level, 1 hPa resolution. 0 = pressure <800 hPa, 1-401 = 800 – 1200 hPa, 402 = pressure>1200 hPa, 511 = data unavailable = default, (403-510 = Reserved for future use).
Air pressure tendency	2	Air pressure tendency 0 = steady, 1 = decreasing, 2 = increasing, 3=undefined

Table A-13. Weather report (Continued).

Parameter	Number of Bits	Description
Sensor Data Description	3	Indication of data for air pressure. 0 = no data = default, 1 = real time with Quality Control, 2 = raw real time, 3 = predicted, 4= nowcast,7 = Sensor unavailable. (5-6 = reserved for future use).
Salinity	9	Salinity in 0.1‰ (ppt) increments. 0.0 – 50.0 ‰, 50.1 = salinity greater than 50.0, 510 = data unavailable = default, 511 = sensor unavailable; (502 - 509 = Reserved for future use).
Spare	25	Set to 0, reserved for future use.
Total number of bits	85	

A.3.11 Air Gap / Air Draught

Table A-14. Air gap/air draught.

Parameter	Number of Bits	Description
Air Draught	13	The vertical distance measured from the ship's waterline to the highest point on the ship in 1cm increments. 1-8,190cm (81.9m); 8191 = distance>81.9m; 0 = Data unavailable = default.
Air gap	13	The vertical distance measured from the surface of the water to the sensor in 1cm increments. 1-8,190cm (81.9m); 8191 = distance>81.92m; 0 = Data unavailable = default.
Air gap trend	2	Trend of the air gap measurement. 0 = steady 1 = rising 2 = falling 3 = no data
Forecast Air Gap	13	The forecast vertical distance measured from the surface of the water to the sensor in 1cm increments. This is the measurement for the time of the forecast 1-8,190cm (81.9m); 8191 = distance>81.92m; 0 = Data unavailable = default.
Valid Time of Forecast	This is the date and time for the forecast. Minute resolution.	
	5	UTC Day of the forecast: 1-31; 0 = UTC day not available = default.
	5	UTC hour of the forecast: 0-23; 24 = UTC hour not available = default; (25-31 = Reserved for future use).
	6	UTC minute of the forcast: 0-59; 60 = UTC minute not available = default; (61-63 = Reserved for future use).
Spare	28	**Set to zero**. Reserved for future use.
Total number of bits	85	

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APPENDIX B. SOFTWARE DETAILS

B.1 The Fetcher/Formatter operation follows these steps.

1) Fetcher/Formatter initiates a Web Services connection and data query to the NOAA PORTS server every three minutes (this value is configurable) and retrieves the PORTS data. The NOAA data is updated every 6 minutes on even multiples of 6 minutes.
2) Fetcher/Formatter initiates a TCP/IP client socket connection to the Queue Manager (QM) TCP/IP server running on port 4500 and sends out identification sentence: “FetcherFormatter Tampa.”
3) FF sends the QM the reports (sensor reports, zone reports etc) as binary data as well as some additional tags that describe what type of report it is, the time, the priority, and the area to be transmitted.
4) Fetcher Formatter sends CSV data sentences in the following format:

   a. BMS, Site Name, Geographical Area of Validity upper corner Lat/Lon and lower corner Lat/Lon, Station/Zone ID, Message Type (Env or Zone Msg type from Tables Zone plus 1000), FF Priority, Time in Unix Seconds (0 for static data), DAC-FI (16 binary bits), binary data.
      i. Site Name = this is the Ports and Waterways Safety System (PAWSS) Site name (i.e. VTS name) or code perhaps, passed through to PAWSS – or the AIS Radio Interface if not using PAWSS.
      ii. Geographical Area of Validity = area over which the message will be transmitted (specific transmitters to be used to reach this area to be determined by PAWSS). Specify the Longitude then Latitude of the upper left corner then the lower right corner.
      iii. Station/Zone ID = ID of sensor station for environmental messages.
      iv. Message Type = this defines the subtype of the message. For environmental messages is the value from Table 3 (0-15).
      v. FF Priority = priority value assigned by the FF. 10 = highest priority, 1 = lowest priority, 0 = priority not set by FF (default).
      vi. Time in Unix seconds = Unix or POSIX time is defined as the number of seconds elapsed since midnight Coordinated Universal Time (UTC) of January 1, 1970, not counting leap seconds. For environmental messages, this is the time of the sensor data in the sensor report (oldest time stamp if the data comes from more than one individual sensor).
      vii. Designated Area Code – Function Identifier (DAC-FI) = this is the 16 binary bits of the DAC and FI. DAC is usually 366 and FI is 33 for Environmental (0101101110100001).
      viii. Binary data = the binary application data – for environmental messages this will be a single sensor report.

   b. Here is an example sentence:
      i. BMS, Tampa, 101.5555, -74.543, 104.214, -72.102, 3, 3, 0, 1215819000, 0101101110100001, 00110101110011011110000001101000000000001001101000000010100000000000100101000000000010010000000000000000000000000

5) At the end of the transmission, Fetcher/Formatter sends out “No Data” and closes the connection.

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APPENDIX C. PILOT LOG SHEET

Tampa Bay Pilots Log Form

Pilot's Name:

		1. Ability to receive the PORTS data											2. When did you primarily use the *PORTS* data? (check one)				3. Briefly describe how the *PORTS* data was used. (check one)				4. Is data delivery via AIS Binary broadcast better than alternative means? (check one)		5. Which do you prefer for the display of the PORTS data on your PPU? (check one)			
		Transit (check one)		Always available? (check one)			Intermittent/ inconsistent? (check one)			Any noticeable latency? (check one)																
Date/ time period	Vessel Name	Inbound	Outbound	Yes	No	Uncertain	Often	Occasional	Never	No	Yes	# of secs	Before going onboard	When first onboard	During transit	Never/rarely	Not a factor	Under-keel clearance	Go-no go decision	Other (describe in comments)	Yes	No (explain briefly in comments)	Text only	Graphical	Both	No preference
	Comments:																									
	Comments:																									
	Comments:																									
	Comments:																									
	Comments:																									
	Comments:																									
	Comments:																									

Please FAX to 860-701-0295 or scan and e-mail to gwjohnson@alionscience.com

Figure C-1. Pilot log sheet.

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