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AIS ASM Operational Integration Plan

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AIS ASM Operational Integration Plan

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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. In addition to providing a means for maritime administrations to effectively track the movement of vessels in coastal and inland 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 using Application Specific Messages (ASMs). The United States Coast Guard Research and Development Center has developed processes to manage the ASMs. Several standard ASMs have been defined and methods have been developed for message creation, routing, queuing, transmission and monitoring. An AIS transmit architecture aligned with International standards has been developed to implement the efficient and robust transmission of ASMs. This report describes the architecture and various components of that architecture including an AIS router and ASM Manager to implement the queuing and prioritization algorithms. Results of testing AIS routers, base stations and the ASM Manager are presented along with recommendations for operational use. An integration plan of the proposed AIS Transmit architecture with the current Nationwide AIS architecture and the Ports and Waterways Security System is also presented along with interfaces to external agencies that provide maritime safety and security information. The agencies include National Oceanic and Atmospheric Administration, United States Army Corps of Engineers, National Marine Sanctuary, and the National Weather Service.					
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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 and inland 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.

Since 2007, the United States Coast Guard Research and Development Center (RDC) has been working on an AIS Transmit Project to determine what additional information is required by AIS users, recommend how the information should be transmitted, and test the transmission of this information at test bed sites. This information is transmitted using AIS Application Specific Messages (ASMs). Several standard ASMs have been defined and prototype methods have been developed for message creation, routing, queuing, transmission and monitoring.

This report describes the AIS system architecture developed by RDC that is in alignment with International Standards, and meets the need for a cohesive, flexible, and robust system for the transmission of electronic Maritime Safety Information (eMSI). Two key components of the AIS Transmit architecture are the AIS Router and ASM Manager, which are discussed in detail.

The primary component that implements the AIS-Logical Shore Station (LSS) is an “AIS Router;” so called, because it is responsible for routing the AIS data between the AIS service clients and the AIS-Physical Shore Station (PSS). A market survey conducted by RDC identified four major commercial vendors that supply AIS Routers as part of their AIS shoreside network software: Kongsberg C-Scope, Gatehouse AIS, Transas AIS Network, and CNS DataSwitch. RDC conducted testing of the four AIS routers to determine data throughput and client connection capacity. The test results show that any of the four commercial systems would be suitable for the current USCG traffic conditions.

The ASM Manager is software that adds the required queuing and prioritization algorithms to the AIS router. This is not commercially available, so software was developed to layer this functionality on top of an AIS router. The ASM Manager performs the following tasks.

1. Ensures ASM messages are valid before transmission.
2. Monitors Very High Frequency (VHF) Data Link (VDL) and ASM demand and adjusts the transmit rate so as to not overload the VDL.
3. Allows for user-specified priorities along with prioritization based upon message type and content.
4. Determines if a message should be transmitted from a given transmitter based upon location.
5. Ensures messages are transmitted.
6. Keeps messages in queue until acknowledgement is received from the Base Station.
7. Allows for acknowledgements to be routed back to user.
8. Manages the repetition of messages that need to be retransmitted on a periodic basis.

The results of base station testing and how the results impact the transmit architecture are also presented. There are two methods for delivering the information to an AIS base station so that it can transmit an AIS message: using a National Maritime Electronic Association (NMEA) Broadcast Binary Message (BBM) (or Addressed Binary Message (ABM)) sentence and by using a VHF Datalink Message (VDM) sentence. In addition, there are two main channel access modes that a base station can use: Fixed Access Time Division



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Multiple Access (FATDMA) and Random Access Time Division Multiple Access (RATDMA). Each of these modes was tested using two different AIS base stations and some differences were observed in performance. Since the USCG uses the L-3 Protec base station, the architecture needs to be based on the L-3 performance. Either VDM or BBM/ABM sentences can be used. Since the L-3 only uses a 1-minute interval for BBM sentence transmission a 1-minute interval on the ASM Manager queue works well. Using FATDMA mode only is the most efficient, since if RATDMA mode is needed then there needs to be sufficient reserved slots in each 4-second window to handle the ASM manager traffic (meaning about 15 times as many slots reserved).

Additionally, the report presents a mapping of AIS transmit message types onto the recommended transmit methodology based upon the results of RDC testing. There are three ways to have a base station transmit an AIS message; each method has pros and cons, and some AIS messages are better suited to certain methods. The recommended types of messages are listed under the three methods of transmission.

1. Base Station Programming

- AIS Message 4 – base station report
- AIS Message 17 – Differential Global Navigation Satellite System (DGNSS) corrections broadcast
- AIS Message 20 – data link management
- AIS Message 24 – extended base station information (if supported by the base station)
- AIS Message 22 – channel management (if using Area-based channel management)
- AIS Message 21 – AtoN (if only a few virtual or synthetic aids, with static parameters)

2. NMEA Message Programming

- AIS Message 6 – addressed binary message
- AIS Message 8 – broadcast binary message
- AIS Message 12 – addressed safety-related text
- AIS Message 14 – broadcast safety-related text
- AIS Message 25 – short unscheduled binary transmission
- AIS Message 26 – scheduled binary transmission
- AIS Message 22 – channel management (if used for specific station channel management)
- AIS Message 10 – request Universal Time Coordinated (UTC) date/time (this is not supported under the current L-3 firmware but will be in the next revision)
- AIS Message 15 – request for specific message(s) (base station will generate an ABK for this so gives additional status)
- AIS Message 16 – assignment mode (especially if assigning slots that then need to be reserved)
- AIS Message 21 – AtoN (for virtual or synthetic aids, with parameters that need to be changed by the client application periodically – perhaps due to monitoring)

3. Directly Created AIS Messages

- AIS Message 16 – assignment mode (for assigned rate mode only)
- AIS Message 21 – AtoN (for virtual or synthetic aids, if too many for the base station to manage using other methods)
- AIS Message 24 – extended base station information (if base station does not support sending the message automatically – this is the case with the L-3 Protec)

The AIS transmit architecture also require integration into the Vessel Traffic Service's (VTS's) operational system (Ports and Waterways Safety System (PAWSS) and the Nationwide Automatic Identification System (NAIS) architectures. This report discusses the key architecture features for integration into these USCG systems.



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Transition strategies are presented to migrate the RDC AIS Transmit capabilities into operational AIS systems at the three test bed sites - Tampa Bay, FL; Stellwagen Bank, MA; and Columbia River, WA; and the future Vessel Traffic Service systems being developed under PAWSS.

Interfacing the AIS Transmit architecture with agencies that provide maritime safety and security information for ASMs is also discussed. A transmit architecture is proposed to interface with various agencies to access required information. Two examples discussed are the NOAA National Marine Sanctuary (NMS) and the United States Army Corps of Engineers (USACE). The NMS provides a variety of important marine protection information to the mariner such as Seasonal Management Areas, Right Whale Listening Buoys, Dynamic Management Areas, areas to be avoided, Mandatory Ship Reporting Areas, and recommended routes. NOAA's National Ocean Service (NOS) provides accurate real-time information such as water levels, currents, and other oceanographic and meteorological data. The USACE provide river lock information and river level and current data on the Inland Waterways.



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LIST OF ACRONYMS AND ABBREVIATIONS

ABK	Addressed and Binary Broadcast Acknowledgement
ABM	Addressed Binary Message
ACK	Acknowledgement
AIS	Automatic Identification System
AOR	Area of Responsibility
ARI	AIS Radio Interface*
ASM	Application Specific Message
AtoN	Aids to Navigation
BBM	Broadcast Binary Message
BS	Base Station
CMTS	Committee on the Marine Transportation System
CPU	Central Processing Unit
C3CEN	USCG Command, Control, and Communications Engineering Center
DAC	Designated Area Code
DGNSS	Differential Global Navigation Satellite System
DS	Data Switch
FATDMA	Fixed Access Time Division Multiple Access
FF	Fetcher/Formatter*
FI	Function Identification
GIS	Geographic Information System
GN	Geographic Notice
GUI	Graphical User Interface
HMI	Human Machine Interface
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IATT	Interim Authority to Test
IEC	International Electrotechnical Commission
IMO	International Maritime Organization
IP	Internet Protocol
ITU	International Telecommunication Union
LOMA	Lock Operations Management Application
LSS	Logical Shore Station
MPI	Message Passing Interface*
NAIS	Nationwide AIS
NMEA	National Maritime Electronic Association
NMS	National Marine Sanctuary
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NWS	National Weather Service
PAWSS	Ports and Waterway Safety System
PCU	PSS Controlling Unit
PORTS	Physical Oceanographic Real-Time System
PRDC	Proprietary RDC Messages
PSS	Physical Shore Station
QM	Queue Manager*



LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

RATDMA	Random Access Time Division Multiple Access
RDC	Research and Development Center
RTCM	Radio Technical Commission for Maritime Services
SCC	Sector Command Center
SDLC	System Development Life Cycle
SM	Service Management
SQL	Structured Query Language
STDMA	Self-organizing Time Division Multiple Access
TCP/IP	Transmission Control Protocol/Internet Protocol
TFR	Transmit Feedback Report
TV32	Transview (32 bit edition)
US	United States
USACE	U.S. Army Corps of Engineers
USCG	United States Coast Guard
UTC	Universal Time Coordinated
VDL	VHF Data Link
VDM	VHF Datalink Message
VHF	Very High Frequency
VTC	Vessel Traffic Center
VTs	Vessel Traffic Service
WM	Waterways Management
XML	Extensible Markup Language

*RDC/Alion developed software



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 and inland waters, AIS can be a means to transmit information from shore to ships in port or underway that contributes to safety-of-navigation and protection of the environment.

In the United States, it is intended that this additional information be transmitted from shore-side AIS base stations in a binary message format as part of an e-Navigation strategy. e-Navigation is defined in the Committee on the Marine Transportation System (CMTS) e-Navigation Strategy Action Plan [1] as:

“e-Navigation is the harmonised collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth to berth navigation and related services, for safety and security at sea and protection of the marine environment”

To implement the e-Navigation strategy into AIS, the United States Coast Guard (USCG) Research and Development Center (RDC) has been working on an AIS Transmit Project since 2007 to research what additional information is required by AIS users, to recommend how the information is transmitted, and test the transmission of this information at test bed sites. As part of the AIS Transmit Project, the RDC has developed processes to manage this information. This information is called AIS Application Specific Messages (ASMs). Several standard ASMs have been defined and prototype methods have been developed for message creation, routing, queuing, transmission and monitoring. Appendix A discusses the background of the AIS Transmit Project.

In general, ASMs are either created by Vessel Traffic Service (VTS) operators, Sector Command Center (SCCs) operators, or retrieved from an information data source, such as the National Oceanographic and Atmospheric Administration’s (NOAA) Physical Oceanographic Real Time System (PORTS) or United States Army Corp of Engineers (USACE) databases. This information is then formatted into ASMs based upon accepted standards. Once formatted, messages are prioritized, geographically identified, and queued. As part of the queuing process, the Very High Frequency (VHF) Data Link (VDL) needs to be monitored and feedback provided to the queuing process to adjust message output. Once formatted, the ASMs are sent to the AIS base station or AIS Aid to Navigation (AtoN) unit for transmission.

In order to have a cohesive, flexible and robust AIS transmit system that meets all user’s requirements, an AIS transmit architecture needs to be fully defined. This report proposes such an architecture and describes the various components of that architecture including an ASM Manager to implement the queuing and prioritization algorithms. These processes also require integration into the VTS’s operational system, Ports and Waterways Safety System (PAWSS), and the Nationwide Automatic Identification System (NAIS) architectures. This report discusses the key architecture features for integration into these CG systems. Results of base station testing and how the results impact the transmit architecture are also presented. Additionally, the report presents a mapping of AIS transmit message types onto the recommended transmit methodology based upon the results of RDC testing.

2 AIS TRANSMIT ARCHITECTURE

RDC has developed a proposed AIS architecture that is in alignment with International Standards. This is described in the sections below after first detailing the International Association of Marine Aids to



Navigation and Lighthouse Authorities (IALA) and International Maritime Organization (IMO) reference architecture for e-Navigation.

2.1 IALA Reference Architecture

The 1998 IMO Performance Standards for AIS [2] state:

1.2 *The AIS should improve the safety of navigation by assisting in the efficient navigation of ships, protection of the environment, and operation of Vessel Traffic Services (VTS), by satisfying the following functional requirements:*

- .1 in a ship-to-ship mode for collision avoidance;*
- .2 as a means for littoral States to obtain information about a ship and its cargo; and*
- .3 as a VTS tool, i.e. ship-to-shore (traffic management)*

This was expanded upon by the International Telecommunication Union Radiocommunications Sector (ITU-R) in the preamble to Recommendation M.1371 [3]:

The ITU Radiocommunication Assembly considering (...)

- b) that the use of a universal shipborne AIS allows efficient exchange of navigational data between ships and between ships and shore stations, thereby improving safety of navigation;*
- d) that although this system is intended to be used primarily for surveillance and safety of navigation purposes in ship to ship use, ship reporting and vessel traffic services (VTS) applications, it may also be used for other maritime safety related communications, provided that the primary functions are not impaired;*
- f) that this system is capable of expansion to accommodate future expansion in the number of users and diversification of applications, including vessels which are not subject to IMO AIS carriage requirements, aids to navigation and search and rescue;*

And further noted in IALA Recommendation A-123, on “The Provision of Shore Based Automatic Identification System (AIS),”[4] which states “National Members and other appropriate authorities should therefore consider the provision of an AIS shore infrastructure so that the full benefit of the system can be realized in terms of navigation safety and protection of the environment.”

IALA Recommendation A-124, “On The AIS Service” [5] provides a service model for the AIS-based shore service component of e-Navigation. The details are described in the various Appendices to A-124. Figure 1 shows the layered structure for this service. The three main functional layers are the Service Management Layer (AIS Service Management Layer or AIS-SM), the Logical Layer (AIS Logical Shore Station or AIS-LSS), and the Physical Layer (AIS Physical Shore Stations or AIS-PSS). Each layer is comprised of “the service component itself, which provides the required functionality in terms of AIS specific data processing; the supporting components and resources, which are exclusively used by the AIS Service, such as computers and local networking devices, i.e. the so called service-owned infrastructure; and the Human Machine Interfaces (HMI) to allow for (remote) access to Technical Operation Personnel.”

The AIS-Service Manager (SM) (described in more detail in Appendix 11 [6] provides for the management of the entire AIS service. This includes configuration and monitoring of all components and an HMI for technical personnel to do the configuration and monitoring.

The AIS-Logical Shore Station (LSS) (described in more detail in Appendix 9 [6] acts as a software router for AIS data going to and from the clients and the AIS PSS Controlling Units (AIS-PCU). It is responsible



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for the management of client and AIS-PSS connections, filtering of data on either or both connections, and data logging.

The AIS-Physical Shore Station (PSS) (described in more detail in Appendix 10 [6] “is an abstract concept that encompasses multiple real physical elements of a shore-based AIS Service.” The major components of an AIS-PSS are: an AIS-PCU that is in charge of controlling one or more AIS fixed stations; at least one AIS fixed station (base station, limited base station, AtoN, or repeater station) that provides the interface to the VDL; and an agent of the AIS-SM to allow for configuration and monitoring of the AIS-PCU and AIS fixed station(s). In some cases all of this functionality can be rolled into one physical component.

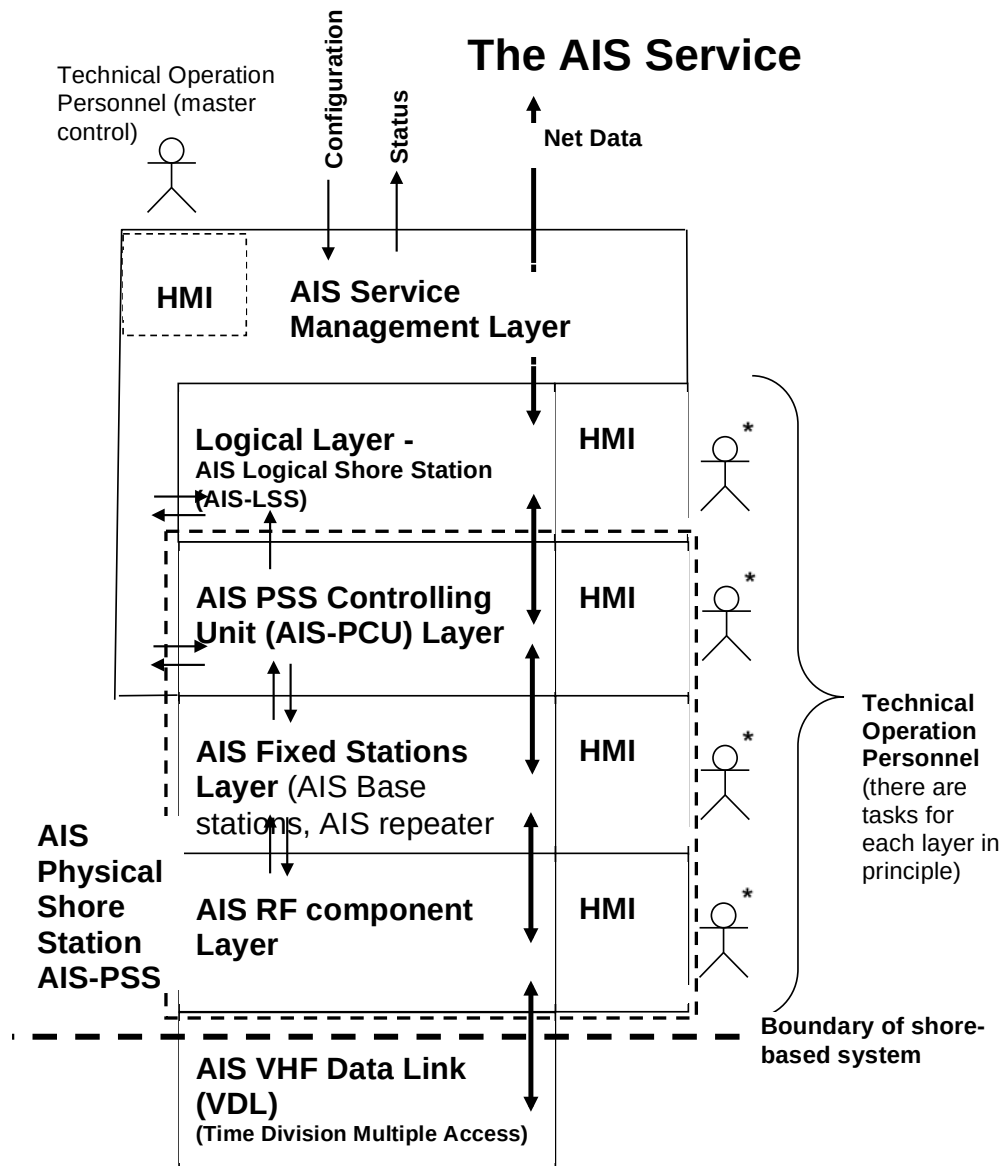


Figure 1. Layered structure of AIS service.
(Structure model of the AIS Service, Figure 4 from [5])



2.2 Proposed Transmit Architecture

One of the major outcomes of the test bed was the identification and quantification of the processes needed in order to create and transmit ASMs: Message Creation, Routing, Transmission, and VDL Monitoring. This is shown in Figure 2. **Message creation** could be accomplished automatically from a database or user-created. If the message created is from a database, then software is needed to fetch the data and put into the correct format (AIS ASM embedded into a National Maritime Electronic Association (NMEA) sentence). If user-created, then software tools (preferably GUI-based) are needed to put the desired information into the ASM. **Message routing** involves both the queue process and rules-based prioritization. This is not available off-the-shelf currently so additional software is needed to accomplish this. **Message transmission** involves routing the message to the correct transmitter according to area (auto or user-specified). **Monitoring** is VDL loading monitoring to ensure that the number of messages desired to be transmitted do not overload the VDL.

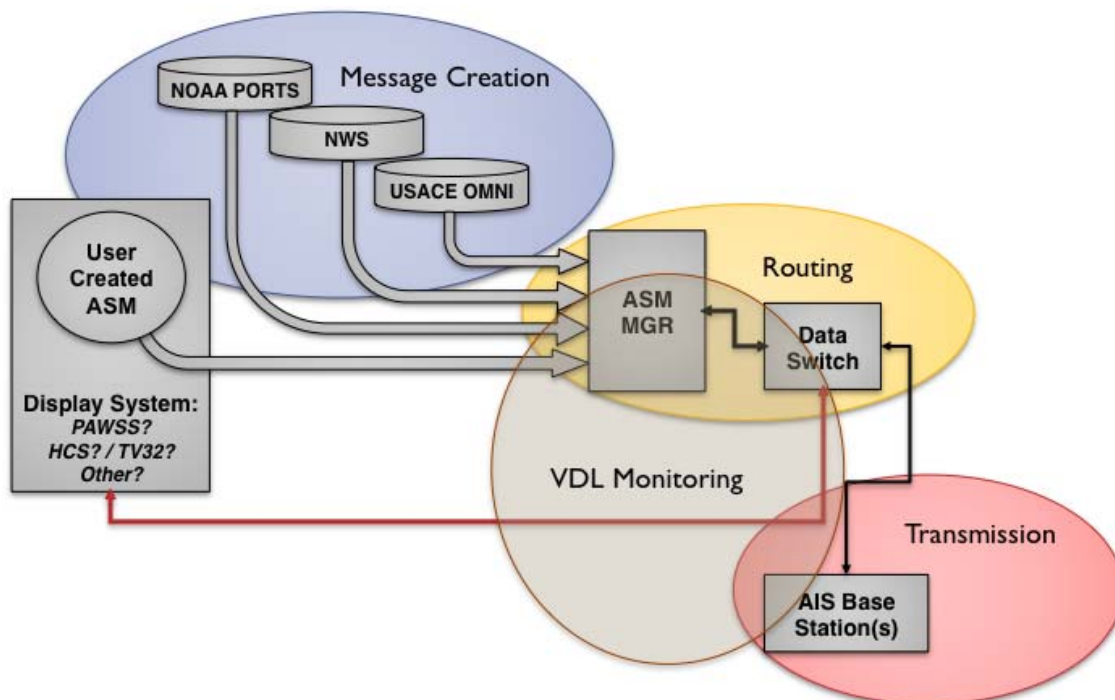


Figure 2. AIS transmit and NAIS integration architecture.

The identification of these processes led to the development of a prototype AIS Transmit architecture, which includes the use of an ASM Manager and an AIS network controller or “AIS router” that routes data between the Physical Shore Stations (PSSs)/AIS Base Stations (BSs) and the various clients (database storage, Geographic Information System (GIS) displays, etc.). This proposed transmit architecture for AIS (shown in Figure 3) is based on the IALA model described above. Each of the major components of the proposed architecture is described in the sub-sections below.

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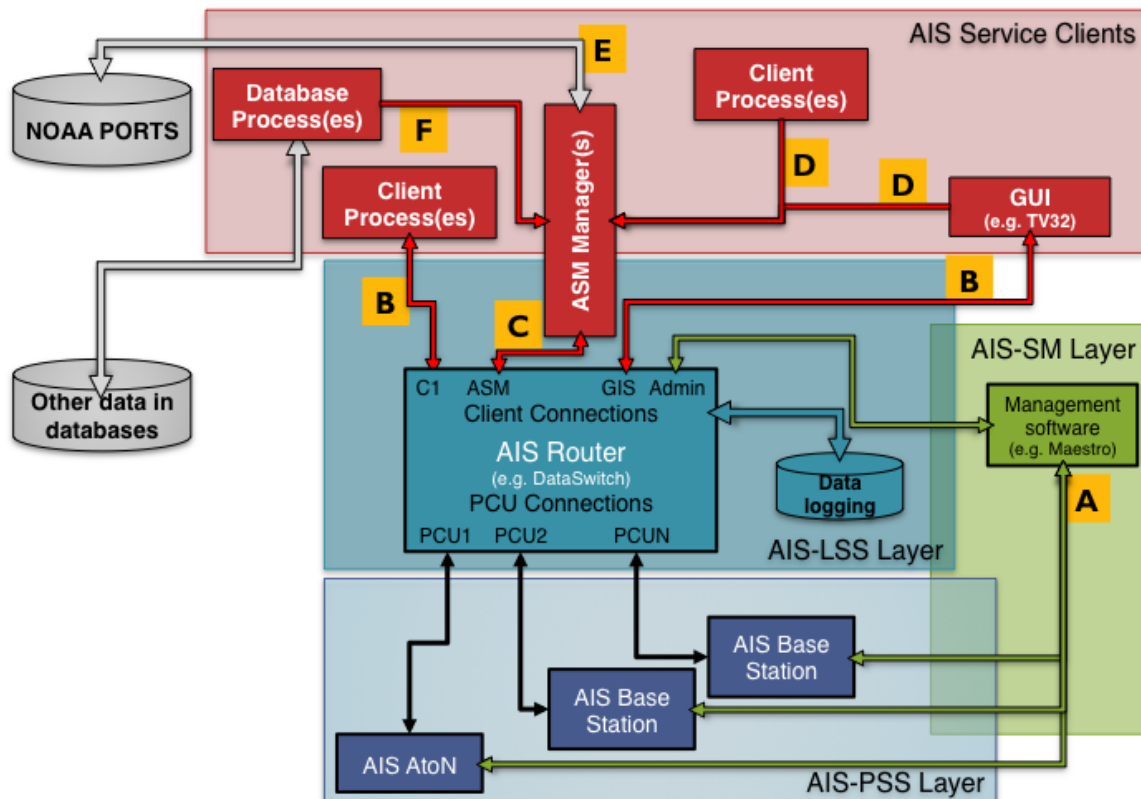


Figure 3. Proposed AIS transmit architecture.

Information Routing Notes (see letters in Figure 3, the AIS message types are explained in Table 1, the ASM Function Identification (FI) is explained in Table 2, the Designated Area Code (DAC) used in the ASM is 367):

- A - AIS-SM is used to program the AIS-PSS (base stations) for AIS Messages: 4, 17 (optional), 20, 23 (optional) and 24 (optional). The AIS-PSS generates AIS Messages 7 and 13 automatically upon receipt of AIS Message 6 or 12 respectively. The AIS-SM can also program AIS AtoNs for AIS Message 21 (optional) or the AIS Base Station for AIS Message 21 (optional Synthetic or Virtual AtoN).
- B - A Client Process is used to collect information from the Users and generate NMEA sentences to initiate (telecommands) AIS Messages: 10, 15, 16, 22, and 23 (optional). This Client Process could be part of GUI C2 System. This same system could also be used to generate AIS Messages 25 and 26 and potential AIS Message 21.
- C - The ASM Manager(s) feed a managed stream of NMEA sentences through the AIS Router to the AIS-PSS to generate AIS Messages: 6, 8, 12, 14, 25, and 26. It is also used to manage any AIS transmit messages created by clients and sent to the AIS-PSS as VHF Datalink Message (VDM) type NMEA sentences.
- D - The Users create ASMs (and text messages) in a client process or GUI, these are embedded in NMEA sentences and sent to the ASM Manager (DAC/FIs: 367/22, 367/35, 367/29,...).
- E - The ASM Manager requests Environmental ASMs from NOAA PORTS (DAC: 367, FI: 22).
- F - Other Database processes retrieve data, format into ASMs (and potentially text messages) embedded in NMEA sentences and forward to them to the ASM Manager for transmission (DAC/FIs: 367/22, 367/35, 367/29,...).



The primary component that implements the AIS-LSS is an “AIS Router;” so called, because it is responsible for routing the AIS data between the AIS service clients and the AIS-PSS. A market survey conducted by RDC identified four major commercial vendors that supply AIS Routers as part of their AIS shoreside network software [7]. All of the software packages allow for multiple client connections (examples shown across the top of the box); each client connection typically has username and password authentication although this is not required in all cases. Each client can be configured for different levels of access and data stream filtering (both send and receive). The software also manages multiple connections to AIS data streams; either from other AIS Routers (in a regional or national hierarchy) or from AIS-PSSs. All of the software packages implement data stream filtering on these connections as well. Different vendors offer different features, but in general they all fully implement the required capabilities of an AIS-LSS.

The other major component of the AIS-LSS is the data logger. This is implemented by all of the vendors in a separate software component that works in conjunction with the AIS Router. Typically this is done using an Oracle or Structured Query Language (SQL) database, but in some cases, flat files are used as well.

RDC conducted testing on the four AIS routers identified in the market survey (Kongsberg C-Scope, Gatehouse AIS, Transas AIS Network, and CNS DataSwitch). Copies of each of software were obtained and installed on a test bed at RDC, running the software on the same computers to allow relative performance comparisons. The systems were run through a series of tests that can be characterized into two categories: basic and performance. The tests were designed to assess the performance of the systems in regards to routing functionality and the criteria that the project sponsor thought most important: raw throughput speed and maximum number of clients possible. Database storage, analytics, and display capabilities were not evaluated, although all of the systems have these capabilities.

Complete details on the testing performed can be found in [7] but the results are summarized here. From a performance standpoint, any of the four commercial systems would be suitable for the AIS router. The overall aggregate traffic load in the United States is currently about 600 messages per second. The systems tested could support from 3,900 to 17,000; all well above the current maximum. The numbers of clients supportable ranged from 35 to 250. CNS supported the most; however, all of the other systems have scalable client modules that would allow for expansion to almost an unlimited number of clients by adding client modules (the reported client counts are for a single instance of the client server modules). How many clients are required, has not been determined.

The study only assessed performance for a few specific criteria; all of the commercial software has much more functionality than that assessed. Much of this functionality would be important for the overall system, and some of the functionality would impact the performance results. For example, setting different filters for each client increases the Central Processing Unit (CPU) loading; especially if geographic filters are used. One of the lessons learned from the study was that the system settings can be critical to performance.

2.3 AIS Router

2.3.1 AIS Router Test Results

Another lesson learned was that an overall architecture for an AIS network that supports full two-way communications needs to be developed. Part of this architecture design needs to include trade-offs on data flow and data storage at the local, regional, and national levels. For example, most of the vendors in this study would recommend down sampling the data as it is aggregated at the regional and then national levels and only store the full time-rate data at the local (or at most regional) levels. Additionally, in order to



specify the hardware and software, the maximum number of clients required to be supported at each connection level (local, regional, national) needs to be determined. This nationwide architecture is **not** reflected in Figure 3.

2.3.2 ASM Manager

The ASM Manager is software that adds additional necessary functionality to the “AIS router.” This is not available off-the-shelf currently, so software was developed to layer this functionality on top of an AIS router. This program was designed to shield the message creator from the details of the base station locations and manage ASM transmissions by performing the following functions:

- G - Ensure messages are valid before transmission.
- H - Monitor VDL and ASM demand and adjusts the transmit rate so as to not overload the VDL.
- I - Allow for user-specified priorities along with prioritization based upon message type and content.
- J - Determine if a message should be transmitted from a given transmitter based upon location.
- K - Ensure messages are transmitted; keep messages in the queue until acknowledgement is received from the BS that they were transmitted.
- L - Allow for acknowledgement of transmission to be routed back to the user.
- M - Manage the repetition of messages that need to be retransmitted on a periodic basis.

ASM Manager accepts Broadcast Binary Message (BBM)-type NMEA sentences containing environmental messages, waterways management messages, text messages and geographic notices from various data feeds. ASM Manager stores those messages in its internal queue. At periodic intervals, ASM Manager forwards messages to a Data Switch(DS). ASM Manager prioritizes and limits the maximum number of messages that are output each minute based upon its configuration parameters (maximum number of messages in a report and maximum number of reports per minute) which are set to maintain a certain level of VDL loading.

ASM Manager has a built-in Transmission Control Protocol/Internet Protocol (TCP/IP) server for receiving BBM sentences from various data feeds. ASM Manager also has a built-in TCP/IP client and Extensible Markup Language (XML) parser for fetching data from the NOAA Physical Oceanographic Real Time System (PORTS) server at a user-configurable rate. Typically ASMs are retrieved from the PORTS server at a 3-minute update rate.

ASM Manager has a built-in mechanism for detecting and purging expired messages. All messages get time-stamped upon reception for use if there is no time of data in the message itself. For environmental and geographic notice messages, ASM Manager parses the date and time from the incoming message and uses that time for detecting message expiration. For other message types, the time of reception is used for detecting expired messages. The expiration period for geographic notice messages is encoded in the binary message. For other message types the expiration period is specified in the configuration file. Expired messages are purged from the queue prior to sending data to a DS.

ASM Manager decodes station ID, data type and sub-type for received messages. If a message with the same station ID and data type and sub-type and same DAC (either 366 or 367) and same FI (either 1, 22, 29, 33, or 35) is already in the message queue, it gets replaced with the updated information. Message priority, number of times message was delayed, number of times message failed to transmit and the next send time are carried over from the obsolete message to the updated message.



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ASM Manager sorts messages by priority and limits the number of messages that get transmitted every minute (set via configuration parameters), so as not to overload the AIS VDL. The message base priority can vary from 1 to 10, with 1 being the highest priority. Messages that fail transmit or get delayed (due to too many messages in the queue), get their priority boosted by 1 for each time that the message is delayed or fails transmit (while its base priority remains the same). If a message is transmitted successfully, its fail to transmit and delay counters get reset, so its priority returns to the base priority. Since the AIS VDL is organized into 1-minute frames, ASM Manager sends out messages once a minute.

ASM Manager monitors the AIS base station feedback for Addressed and Binary Broadcast Acknowledgement (ABK) type NMEA messages that indicate success or failure of message transmission. In case a message is not acknowledged, that message is put back into the transmit queue and its failed transmit counter is incremented. Messages that fail to transmit are scheduled for retransmit in the next minute's transmit cycle.

ASM Manager can accept metadata along with the BBM sentence (repeat rate, priority, and area of transmission) in RDC proprietary type NMEA sentences (PRDC). ASM Manager can filter out messages by area of transmit specified in PRDC sentence if filtering is turned on. PRDC and BBM sentences are expected to follow the following sequence: [optional PRDC][BBM 1 of x]...[BBM x of x].

ASM Manager checks for various error conditions and in case of errors, it generates email alerts about the outages. To reduce the number of emails, a single email alert notice is generated in a 24-hour period that contain all errors and alerts that occurred since the last email was generated.

ASM Manager provides configurable monitoring and logging capabilities and an interactive user interface. The user interface allows turning on and off display of the message queue (before and after each transmit), display of message information, deleting messages from the queue, and stopping program operation.

2.3.3 ASM Manager Logic

The following sections summarize the logical steps that the ASM Manager performs in completing various processes.

2.3.3.1 Input Processes

Server Process

- Wait for connections on TCP/IP port.
- Once connection opened, spawn off a new thread to handle the client and free up server port to accept new connections.
- Receive NMEA 4.0 TAG [8] blocks and BBM sentences. Maintain data received from each open client connection in a separate processing queue.
- Parse \$PRRDC sentence that contains ASM parameters:
 - Repeat interval
 - Priority
 - Geographic area for transmission
- Parse each BBM sentence to ensure the sentence is correct, get time parameters from message.
- NOTE: if ASM Manager receives a BBM sentence that is an unknown DAC/FI then it will be discarded.
- Add the message into the appropriate queue for transmission.



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Client Process

- Initiate connections (to NOAA PORTS) at the defined interval.
- Pass parameters: location and maximum number of slots to use in each message.
- Parse each BBM sentence and ensure sentence is correct, get time parameters from message.
- NOTE: if ASM Manager receives a BBM sentence that is an unknown DAC/FI then it will be discarded.
- Add the message into the appropriate queue for transmission.

Queue Process

- When adding message into the queue, check to see if it is a newer version of a message already there (based upon DAC/FI/Msg ID/Sensor ID/SubType fields). If it is, delete the old message and add the new message with a priority of 1 less than the message just deleted.
- Queue has the following fields
 - Serial number – give the message a sequential number for tracking
 - Type of data (static or dynamic)
 - Message identifiers - info to enable checks for new messages of same type
 - DAC, FI, sensor id/message ID
 - Time into queue – timestamp of when placed in queue
 - Time expires – time the message is no longer valid – this is an explicit parameter in the Geographic Notices. Messages without this parameter get assigned the default value from the configuration file

Repeat interval – how often (minutes) to repeat the message (0 = never)

- Priority – message priority, 1 (high)-10 (low)
 - If the user has specified a priority then message starts with this
 - Default for dynamic data is 5
 - Default for static data is 10
- Data (BBM sentence wrapped into TAG block)

Output Process

- Perform Queue management before each transmit.
 - Remove messages that have expired
- Every minute select N messages from the queue for transmission.
 - N = configurable parameter
 - Messages are selected based on highest priority messages that have in-queue times earlier than current time
- Open a connection to the DS and send the N messages wrapped in TAG blocks.
- Wait for Acknowledgement (ACK) messages back from the DS (from the AIS base station).
- Once ACK messages are received, delete the messages from the queue.
- Generate an alert if ACK messages are not received.
- If the message being deleted has a non-zero repeat interval put it back into the queue with an in-queue time equal to the current time plus the repeat interval.
- For each message that is left in the queue, decrement the priority by 1.

2.3.4 AIS-PSS Layer

Although the IALA model for the AIS-PP layer includes an additional AIS-PCU sub-layer, the USCG installations do not use this. Any functionality of the AIS-PCU layer is handled by the AIS Fixed Stations.



In the case of the Tampa test bed this is an L-3 Protec base station. For the Columbia River, this is two SAAB R-40 base stations. Louisville is currently a SAAB R-40 base station but this is being transitioned to an L-3 Protec. The Stellwagen Bank test bed uses an L-3 AtoN transmitter.

2.4 Base Station Testing Results

There are two methods for delivering the information to an AIS base station so that it can transmit an AIS binary message; using a NMEA BBM (or Addressed Binary Message (ABM)) sentence and by using a VDM sentence. These methods are discussed in more depth in Section 3.1 below. In addition, there are two main channel access modes that a base station can use: Fixed Access Time Division Multiple Access (FATDMA) and Random Access Time Division Multiple Access (RATDMA). In general it is more efficient for the VDL loading for a base station to reserve sufficient slots and use FATDMA for all transmissions. This was examined in our VDL report [9]. However, if RATDMA mode is not enabled, on some base stations, some transmissions may not occur, so in general RATDMA must be enabled.

The IALA and International Electrotechnical Commission (IEC) 62320-1 Ed.1 standards are not totally clear on exactly how a base station should act in various combinations of message types (BBM vs. VDM) and channel access modes. IEC-62320-1 [10] in paragraph 6.3.4.8 describes the base station response to VDM input as the following: [Note: Figure 4 provides Figure 5 from the quotation.]

The Base Station shall transmit, on the VDL, VDM sentences received on the PI. FATDMA shall be used as the access scheme for transmission. RATDMA may also be configured for use. The following rules shall be used for VDL transmission (as shown in Figure 5):

- 1. the VDL message shall be transmitted in available FATDMA slots; NOTE Available FATDMA slots are local 'L' slots without planned ECB transmissions.*
- 2. if FATDMA slots are not available within 4-seconds, RATDMA shall be used;*
- 3. if RATDMA is not available, and if there is an available FATDMA slot within 6-minutes, it shall be used;*
- 4. if FATDMA and RATDMA are not available, there shall be no transmission and the VDM is discarded.*

IEC-62320-1 is silent on what the response should be to a BBM sentence. In order to assess how some base stations actually respond, RDC conducted tests on both the L-3 Protec and Saab R-40 base stations. The results are detailed in the sub-sections below.

2.4.1 L-3 Protec Base Station

With BBM sentences and FATDMA-only mode, only messages that can be sent in the reserved slots in 1 minute get transmitted. ABK sentences stating that transmission is not possible are output for the remainder at 60 seconds after the sentences were presented to the base station. With VDM sentences the radio will try over a longer interval (the IEC standard requires 6 minutes) but due to memory limitations only scheduled 2 minutes worth, which was indicated by Transmit Feedback Report (TFR) sentences. The radio then transmitted messages for an additional 2 minutes. This anomaly is being discussed with the L-3 manufacturer.

With RATDMA enabled, the radio performed as expected. With BBM sentences, as many messages as could be sent in the 4-second response window were sent; any reserved slots in that 4-second window were used. ABKs indicating negative transmission were output at the end of the 4-second (150 slots) window for any other messages that could not be sent. The same response was seen for VDM sentences. TFRs were output for all sentences.



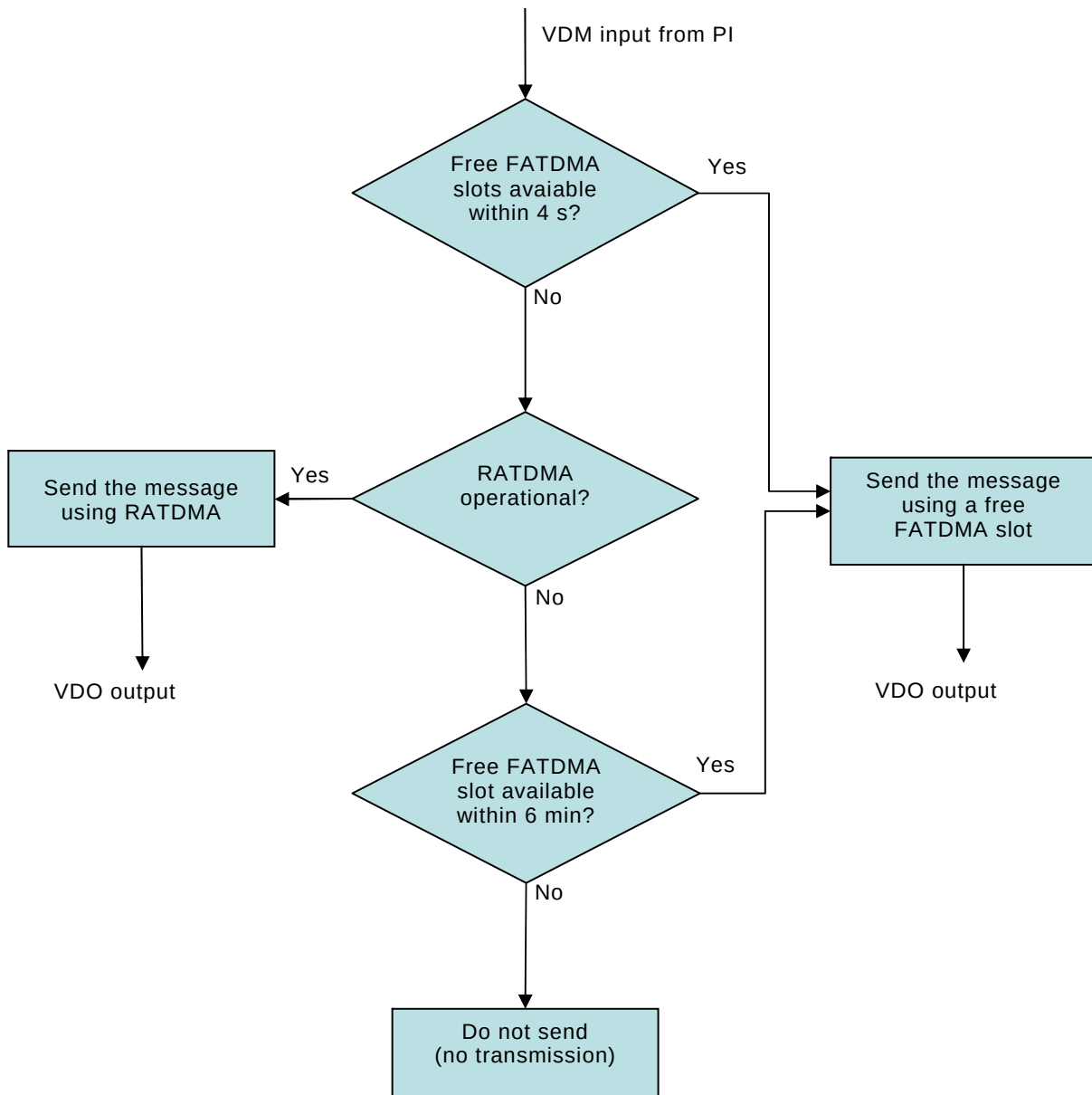


Figure 4. Flow diagram for AIS BASE station response to VDM input.
(Figure 5 from IEC 62320-1[10])

2.4.2 Saab R-40 Base Station

In FATDMA-only mode we could not get the radio to transmit based on a BBM sentence. This flaw is being discussed with Saab. With VDM sentences the radio would transmit the messages in the reserved slots -- even waiting beyond 1 minute for an open slot reservation in order to transmit.

In FATDMA+RATDMA mode the radio transmitted the BBMs instantly. The radio did not appear to implement the randomization algorithm described in ITU-R M.1371 [3] with transmissions randomized over the 4-sec interval. Instead, it appeared the messages were transmitted instantly and in succession. Reserved slots were not used. With VDM sentences, the performance was the same. In discussions with Saab, they claimed that their randomization algorithm although different than that in 1371 was approved by Bundesamt



für Seeschifffahrt und Hydrographie which certifies that the R40 AIS base station complies with the latest specifications contained in the new IEC62320-1 Performance Standard.

2.4.3 Architecture Implications

Since the USCG has standardized on the L-3 Protec, the architecture implications are based on the L-3 performance. Using a 1-minute interval for message queuing on the ASM Manager works well since the L-3 only uses a 1-minute interval for BBM sentence transmission. If RATDMA mode is going to be enabled and it is still desired that most of the transmissions are in reserved slots, then there needs to be sufficient reserved slots in each 4-second window to handle the ASM manager traffic (meaning about 15 times as many slots reserved). If RATDMA can be disabled then it is more efficient for the VDL, since slots for the ASM manager traffic can be spaced across the entire 1-minute frame.

3 MAPPING AIS TRANSMIT MESSAGES TO ARCHITECTURE

The AIS does a great job informing the VTS and Sector Command Center (SCC) of vessel position and identification, but in addition, AIS can be a very effective VTS/SCC tool for communication. AIS accomplishes this by utilizing the transmit capability and AIS binary messages or ASMs. For clarification purposes, transmit is defined to include both AIS broadcast *and* addressed messages. The current AIS specification, ITU-1371-4 [3] defines 27 different AIS messages shown in Table 1. Some of these message types can be grouped into categories applicable to AIS transmit: message types 4, 17, 20, and 24 are base station messages; message types 10, 11, 15, 16, 20, 22, and 23 can be considered *telecommands* that can be used by a VTS for channel management; message types 12, 13, and 14 can be used for safety-related text messages; and message types 6, 7, 8, 21, 25, and 26 are binary messages that can be used for information transfer. Table 2 provides the valid function identifiers for DAC 366/367.

Table 1. AIS message types.

ID#	AIS Message Description
1,2,3	Position Reports – autonomous, assigned, or interrogated
4	Base Station Report – UTC/date, position, slot number.
5	Class A Report - static and voyage related data
6, 7, 8	Binary Message (ASM) – addressed, acknowledge or broadcast
9	SAR aircraft position report
10, 11	UTC/Date - enquiry and response
12, 13, 14	Safety Text Message – addressed, acknowledge or broadcast
15	Interrogation – request for specific messages
16	Assignment Mode Command
17	Binary Message – DGNSS Correction
18,19	Class B Reports – position & extended
20	Data Link Management – reserve slots
21	AtoN Report – position & status
22	Channel Management
23	Group Assignment
24	Class B Static Data
25	Binary Message (ASM)– single-slot
26	Binary Message (ASM) – multi-slot (STDMA)
27	Long-range AIS broadcast message



Table 2. Valid function identifiers for DAC 366/367.

FI	Description
16	Passenger and Crew Count
17	Synthetic Targets Message
22	Geographic Notice USCG
29	Linked Text
33	Environmental USCG
35	Waterways Management USCG
55	USCG Encrypted Text Message
56	USCG Encrypted Position Report
57	USCG Encrypted Static Data
58	USCG Encrypted Target of Interest
63	Water Level

3.1 Message Transmission Options

There are three ways to have a base station transmit an AIS message; each method has pros and cons, and some AIS messages are better suited to certain methods. Each of the methods and the recommended AIS messages are described in the following subsections.

3.1.1 Base Station Programming

A typical base station (such as the L-3 Protec) can be programmed to generate some AIS messages automatically. The AIS-SM layer does the programming – whether this is third-party software such as Maestro or the base station vendor’s software (L-3 Base Station GUI). The messages are configured and assigned to a repetitive transmit schedule. Slots can also be reserved for these messages. There are some AIS messages that would be difficult to create and/or manage by one of the other two transmit methods and so should be sent using this method. The messages that fall into this category are:

- AIS Message 4 – base station report.
- AIS Message 17 – Differential Global Navigation Satellite System (DGNSS) corrections broadcast.
- AIS Message 20 – data link management.
- AIS Message 24 – extended base station information (if supported by the base station).
- AIS Message 22 – channel management (if using Area-based channel management).
- AIS Message 21 – AtoN (if only a few virtual or synthetic aids, with static parameters).

3.1.2 NMEA Sentence Programming

A base station supporting NMEA 4.0 can be configured to transmit most AIS messages using various NMEA sentences. In this case, a client application could create the appropriate NMEA sentences and send them through the network to the base station. The base station uses the information in the sentences to create and transmit the AIS messages. Most messages that a base station can transmit can be configured and sent in this manner. The advantage of this method vs. Base Station Programming is that a client application (not just the AIS-SM) could request the transmission of the AIS message. The advantage of this method vs. Directly Created AIS Messages is that this method does not require the client to know anything about the VDL or the current slot map; the base station handles that when it creates the AIS messages from the information in the NMEA sentences. The messages that are recommended to use this method are:

- AIS Message 6 – addressed binary message.
- AIS Message 8 – broadcast binary message.



- AIS Message 12 – addressed safety-related text.
- AIS Message 14 – broadcast safety-related text.
- AIS Message 25 – short unscheduled binary transmission.
- AIS Message 26 – scheduled binary transmission.
- AIS Message 22 – channel management (if used for specific station channel management).
- AIS Message 10 – request Universal Time Coordinated (UTC) date/time (this is not supported under the current L-3 firmware but will be in the next revision).
- AIS Message 15 – request for specific message(s) (base station will generate an ABK for this so gives additional status).
- AIS Message 16 – assignment mode (especially if assigning slots that then need to be reserved).
- AIS Message 21 – AtoN (for virtual or synthetic aids, with parameters that need to be changed by the client application periodically – perhaps due to monitoring).

3.1.3 Directly Created AIS Message

A base station can be forced to transmit any AIS message by embedding the AIS message in a VDM sentence and sending that to the base station. This allows tremendous flexibility; however, it puts the entire burden of the AIS message creation and VDL management onto the client. The L-3 Protec base station will generate a TFR sentence back to the client upon receipt of a VDM which is very helpful; however, this is not required by the NMEA standard and thus cannot be expected with all base stations. There are several AIS messages that would be very difficult to create and manage using this method, and thus are not recommended for this transmission method (AIS 4, 17 and 20 for example). The messages that **are** recommended to use this method are:

- AIS Message 16 – assignment mode (for assigned rate mode only).
- AIS Message 21 – AtoN (for virtual or synthetic aids, if too many for the base station to manage using other methods).
- AIS Message 24 – extended base station information (if base station does not support sending the message automatically – this is the case with the L-3 Protec).

4 INTEGRATION WITH EXISTING USCG AIS SYSTEMS

The NAIS Acquisition project has an AIS architecture that includes an AIS router, the CNS Systems[™] DataSwitch. In an effort to converge the development efforts and allow for easier integration of efforts, the RDC Transmit Architecture (including the ASM Manager) was designed to work in conjunction with this AIS router. Technically the integration of the proposed transmit architecture with NAIS (see Figure 3) would be very simple; just the addition of the ASM manager next to the CNS DataSwitch.

An initial test of this including the ASM Manager in the NAIS Permanent Transceive system has been proposed by RDC. This addition is shown in Figure 5. The system changes needed are indicated in the diagram by the letters A, B, and C. These changes are:

- A. DataSwitch Changes. Add account for ASM Manager.
 - This account is independent of account(s) on the NAIS side.
 - DataSwitch routes traffic based upon account settings.
 - Think of it as adding another computer to an Ethernet Switch– no impact to existing computers as long as the switch can handle the load.



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- o RDC testing shows that DataSwitch can handle a LOT more loading than it is currently under.
- B. ASM Manager to DataSwitch Physical Connection.
 - Either Serial or Ethernet.
 - o Serial: ASM Manager computer needs to be local to DataSwitch.
 - o Ethernet: requires authorization for ASM Manager to be on OneNet (if DataSwitch is on OneNet?).
- C. ASM Manager connection to Internet.
 - If ASM Manager is on OneNet then use OneNet to access Internet.
 - If ASM Manager is using serial connection to DataSwitch then need access to a separate network connection (either use existing or install cable/DSL/cellular connection).

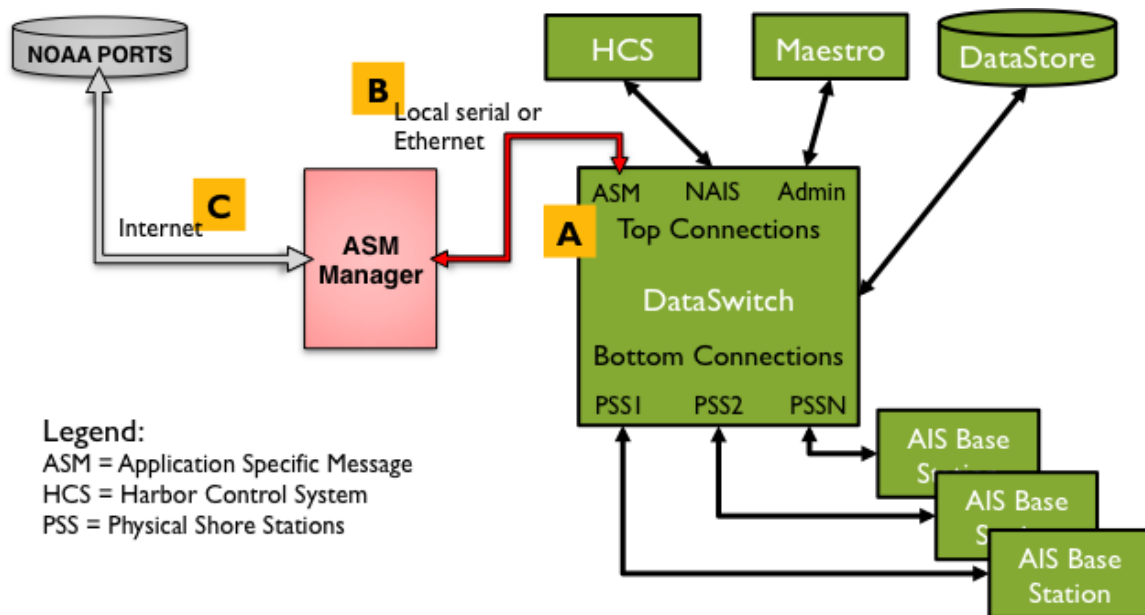


Figure 5. NAIS with RDC transmit Phase 1.

There are currently two USCG programs with AIS base stations – VTS and NAIS. Each of these programs uses a different architecture, which is currently not compatible with sharing of the AIS base stations. PAWSS is a major acquisition project to build new Vessel Traffic Services where necessary and replace existing systems. VTS currently (see Figure 6) uses a direct connection (serial over Internet Protocol (IP)) from PAWSS to the Physical Shore Stations (PSS), which typically consists of a single AIS base station. In contrast, NAIS uses a backbone architecture based upon the CNS Systems DataSwitch to connect to the PSSs.



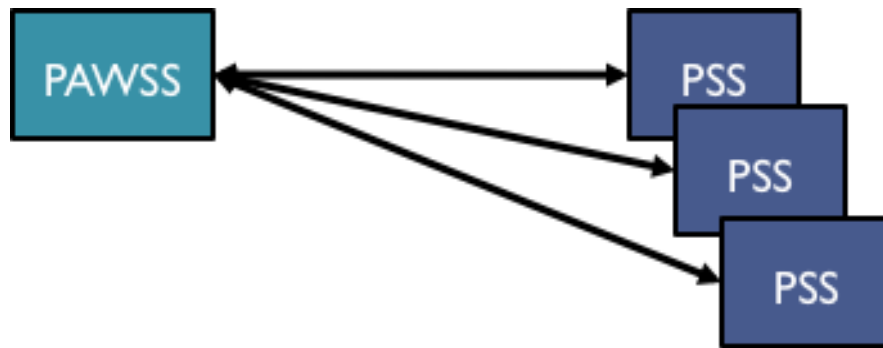


Figure 6. VTS with PAWSS, current configuration.

There has been some discussion on how to allow the two systems to share the PSSs. One concept would be to build in dual connections to each PSS and have the two systems operate in parallel (see Figure 7) where NAIS is in green and VTS (PAWSS is in light blue). However, this requires additional communications lines to each PSS and thus is costly. However, the RDC's AIS Transmit architecture could be used as a way to allow these two systems to operate together; specifically, by using the DataSwitch (DS) to provide the sharing of the PSSs (see Figure 8). This eliminates the cost of the extra communications links, allows for AIS Transmit to be integrated into the architecture through the DS, and includes the addition of the ASM Manager as a value-added component. In Figure 8, an additional “backup connection” box is shown to indicate that due to the criticality of the VTS function, there must be a backup to the DS component. This backup could either be a redundant DS or a failover to direct connections between PAWSS and the PSSs. Figure 9 shows the proposed AIS Transmit Architecture with both NAIS and PAWSS.

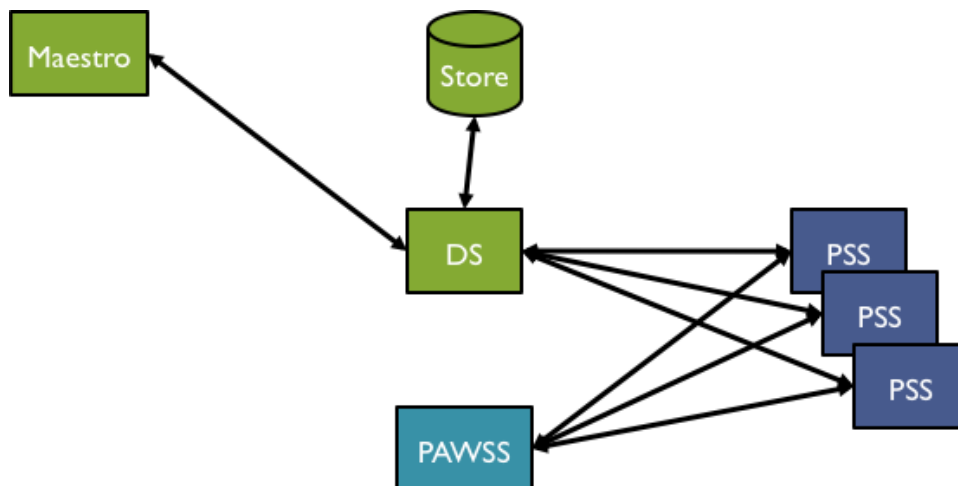


Figure 7. NAIS overlay to VTS PAWSS.

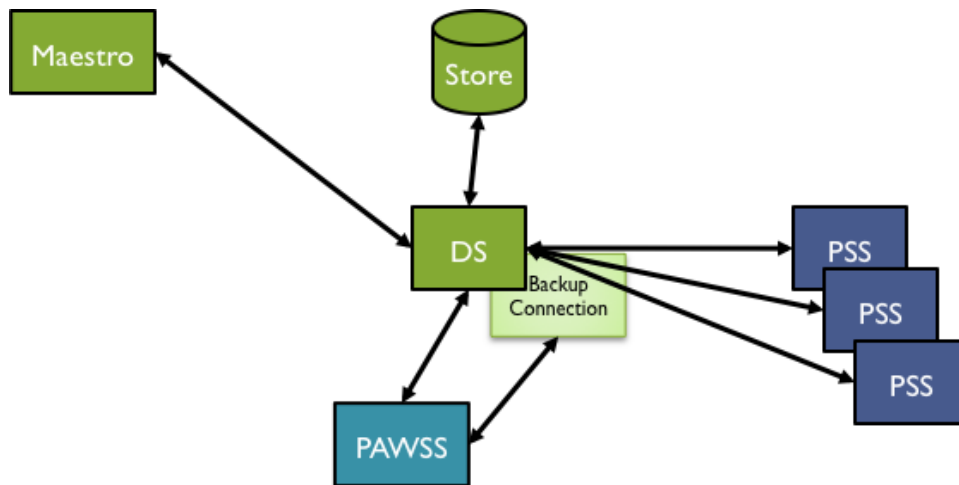


Figure 8. NAIS integrated with PAWSS.

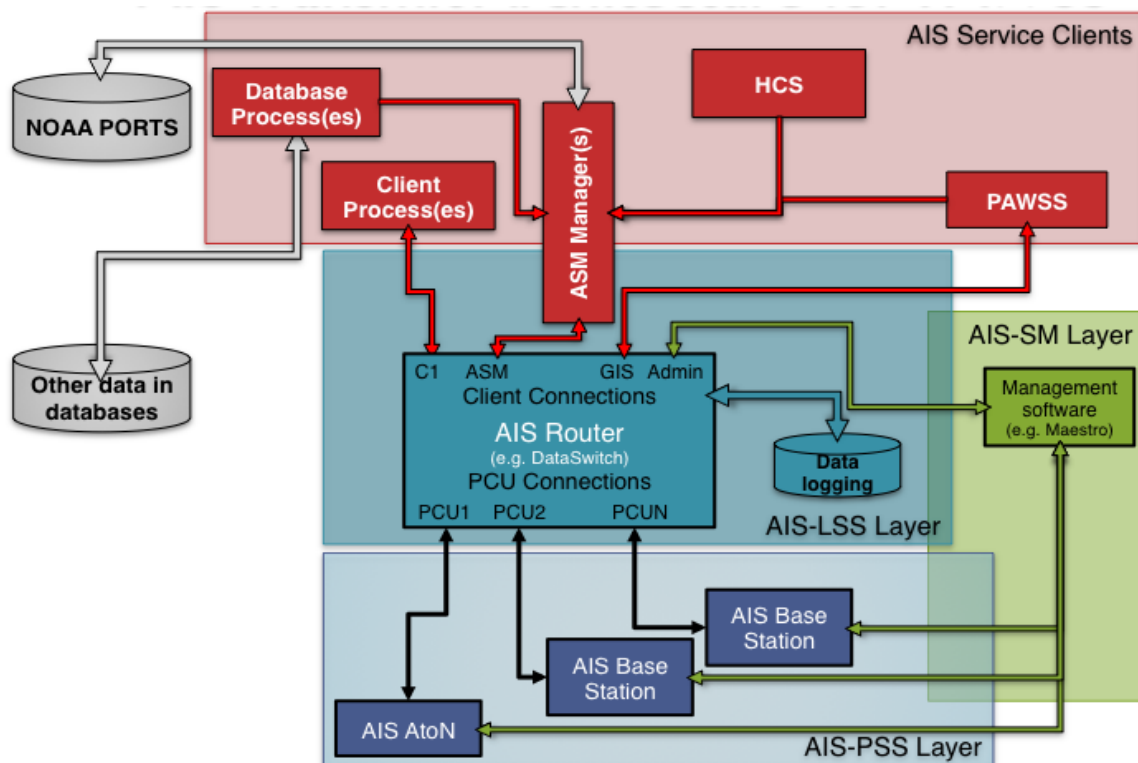


Figure 9. AIS transmit architecture with NAIS and PAWSS.

5 TRANSITION STRATEGY

5.1 Tampa Transition

Tampa is the oldest and most mature test bed, making it a prime candidate for transition to being fully integrated into an operational VTS. Various transition options for the entire VTS system were proposed in 2010 [11]. None of these were selected and in 2011, a proposed transition strategy for just Tampa was developed [12] with the goal of moving the Tampa test bed to an operational system. Under this transition

plan, there would have been little, if any, impact on the daily routine of the VTS watchstanders. With the exception of new computers onsite for running the back-end processes, the VTS watchstander would have seen little change as a result of VTS Tampa assuming full responsibility for the system. The major impact of this transition would have been centered on the maintenance and repair of the system. There are specific functions that RDC currently performs, such as:

1. AIS operating software maintenance
2. AIS operating software upgrades
3. Network maintenance (off-site)
4. Incoming data issues
5. Software troubleshooting and repair
6. Hardware troubleshooting and repair
7. Initial training
8. Updating of all documentation

Under the planned post-transition state, all of these functions would have been the responsibility of Tampa's VTS Director.

After discussion with VTS Tampa, the VTS Program Manager, and NOAA, it was decided that the best course of action going forward for transitioning Tampa to Operational status was to turn over Physical Oceanographic Real Time System (PORTS) Transmit operations to NOAA. As of the date of this report, the original test bed in Tampa is in the process of being converted into an operational system under the control of NOAA. As part of the transition, the architecture (and software processes) are being upgraded to the current version as shown in Figure 2 (currently parallel processes are being run at RDC to generate both old and new message formats to allow for a transition period for the Tampa pilots). Message Creation will be automatic from PORTS. The PORTS data is requested directly by the ASM Manager, which will accomplish the Message Routing. The ASM Manager will run on a computer at NOAA's Silver Spring, MD location and connect directly to the AIS base station in Largo, FL. NOAA will request an NAIS data feed in order to monitor the transmissions from the Palmetto NAIS receive site. It is expected that this transition will be complete by September 2013.

5.2 Columbia Transition

The Columbia River test bed was turned over to the Volpe Center in 2010. Since the Volpe Center already managed the base stations for the Columbia River Pilots, this was an easy handoff. In 2013 RDC worked with Volpe Center to update the architecture and message formats to the current specification. As of the date of this report, this transition to the new message generation architecture and new message specifications is in process. It is expected that this transition will be complete by September 2013.

5.3 Stellwagen Bank Transition

In 2010, National Marine Sanctuary (NMS) agreed to take over operation of the Stellwagen Bank AIS Transmit operations although RDC maintained control of the AIS transmitter. This involved transferring some processes and monitoring responsibility from RDC to NMS. The Queue Manager process was moved to Cornell and is monitored along with the Fetcher/Formatter that is already there. The AIS Radio Interface (ARI) remained running on a computer at Provincetown. System monitoring responsibility shifted from RDC to NMS. This was complete in August 2010. The AIS base station at Provincetown was replaced with an AIS AtoN transmitter by UNH in Jan 2011.



During 2013, RDC has worked with NOAA to update the system to the current architecture and message specification, although this has not been completed to date. The plan is also to turn over the transmitter once appropriate authorizations are in place. NMS has requested the frequency authorizations for this transition.

5.4 PAWSS Transition

Since 2010, RDC has developed several options for transitioning PAWSS into an AIS Transmit capable system. Several options were proposed in 2010 [11] but not executed. More recently, a simpler approach to integrating PAWSS was proposed to be tested in three phases; although this has been on hold awaiting the completion of PAWSS software upgrades to the new version (MTM300).

5.4.1 Phase 1 – PAWSS DataSwitch Integration Verification

The purpose of this testing is to demonstrate that PAWSS can work (transparently for the VTS operator) by connecting to the AIS base stations via a CNS DataSwitch vice direct connections. This is important because if we change to this configuration it enables the implementation of AIS Transmit (in the short term) in all VTS ports without having to modify PAWSS at all. The longer term solution is to modify PAWSS to add in the capability to create/send and decode/display the AIS ASMs, but using a DataSwitch also enables the AIS base stations to be shared more easily and would be needed in the future configuration anyway. The CNS DataSwitch was selected for this integration as opposed to some other commercial product because it is part of NAIS and this would facilitate future integration of VTS into the NAIS network.

5.4.2 Phase 2 – PAWSS DataSwitch Integration Operational Test

The purpose of this testing is to demonstrate that the PAWSS-DS integration can work (transparently for the VTS operator) in an operational setting. The plan is to include the AIS Transmit testing in conjunction with the PAWSS MTM300 testing to be done at VTS San Francisco. The IATT for the MTM300 (new version of PAWSS software) testing would be extended to include the AIS Transmit testing, which would be added on at the end of the test period. Both qualitative and quantitative assessments are planned.

5.4.3 Phase 3 – PAWSS ASM Integration

The final step would be to include the ability within PAWSS to both encode and decode the ASMs. This would require programming modifications by Lockheed Martin. A previous estimate was for 175 man-days to do this. The timeline for this is totally a function of USCG Command, Control, and Communications Engineering Center (C3CEN) and Lockheed Martin and what priorities are set by C3CEN/USCG Headquarters.

5.5 SDLC process

The final transition effort has been the initiation of the System Development Life Cycle (SDLC) process for the ASM Manager. The goal of this effort is to get the ASM Manager accepted as an approved USCG C4I System and authorized for use on the CG OneNet. This will facilitate implementation CG-wide and will help to address many security issues.

6 INTERFACES TO OTHER AGENCIES (NOAA, USACE)

6.1 NOAA

The USCG, NOAA National Marine Sanctuary (NMS) and NOAA Physical Oceanographic Real Time System (PORTS) have been working together to develop various aspects of AIS broadcast capability



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through standards development, software development, and field testing. USCG and NOAA are strengthening their partnership with the goal of implementing a joint, AIS Aids to Navigation (AtoN) capability with both NMS and PORTS information.

6.1.1 Roles

NOAA National Marine Sanctuary (NMS) provides a variety of important marine protection information to the mariner such as:

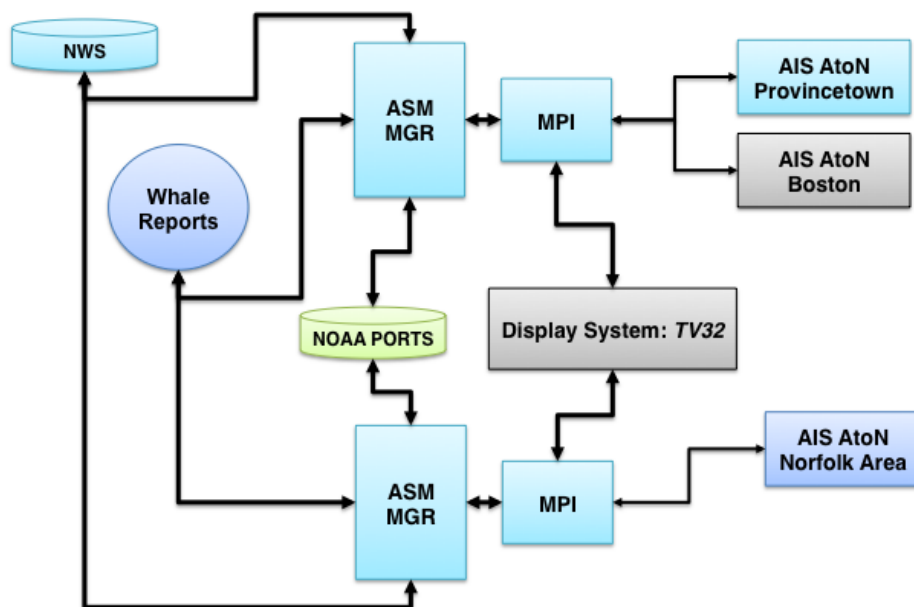
- Seasonal Management Areas
- Right Whale Listening Buoys
- Dynamic Management Areas
- Areas to be Avoided
- Mandatory Ship Reporting Areas
- Recommended Routes

NOAA's National Ocean Service that provides PORTS, a program that supports safe and cost-efficient navigation by providing ship masters and pilots with accurate real-time information such as real-time water levels, currents, and other oceanographic and meteorological data.

The USCG is the competent authority for the Nationwide AIS network and is responsible for the management and coordination of all AIS ASM transmissions in the US.

6.1.2 System Architecture

A proposed demonstration architecture is shown in Figure 10. NOAA and the USCG have been proceeding towards implementing this in the Chesapeake Bay, VA area as a test.



Light blue = USCG RDC, Green = NOAA, Gray = Volpe, Dark Blue = Stellwagen Bank

Figure 10. USCG-NOAA Chesapeake Bay AIS transmit partnership – MPI stands for Message Passing Interface.



6.2 USACE

The USACE has been working to implement their LOMA (Lock Operations Management Application) system for the past couple of years. In addition to the lock management functions, it is intended that this system also integrate with the USCG AIS system for exchange of AIS data and sharing of transmitters for the broadcast of Marine Safety Information (see Figure 11). One area that the USCG will be working with USACE directly is on the implementation of broadcasts of water current information from the lock current models. The USACE is developing models of the water currents around the locks based upon bathymetry, water level, dam outflow, etc. These models generate a field of water current vectors (see Figure 12). RDC is working with USACE to develop the processes and procedures to select some of these water current values from the thousands produced by the model and transmit them to the mariners via AIS.

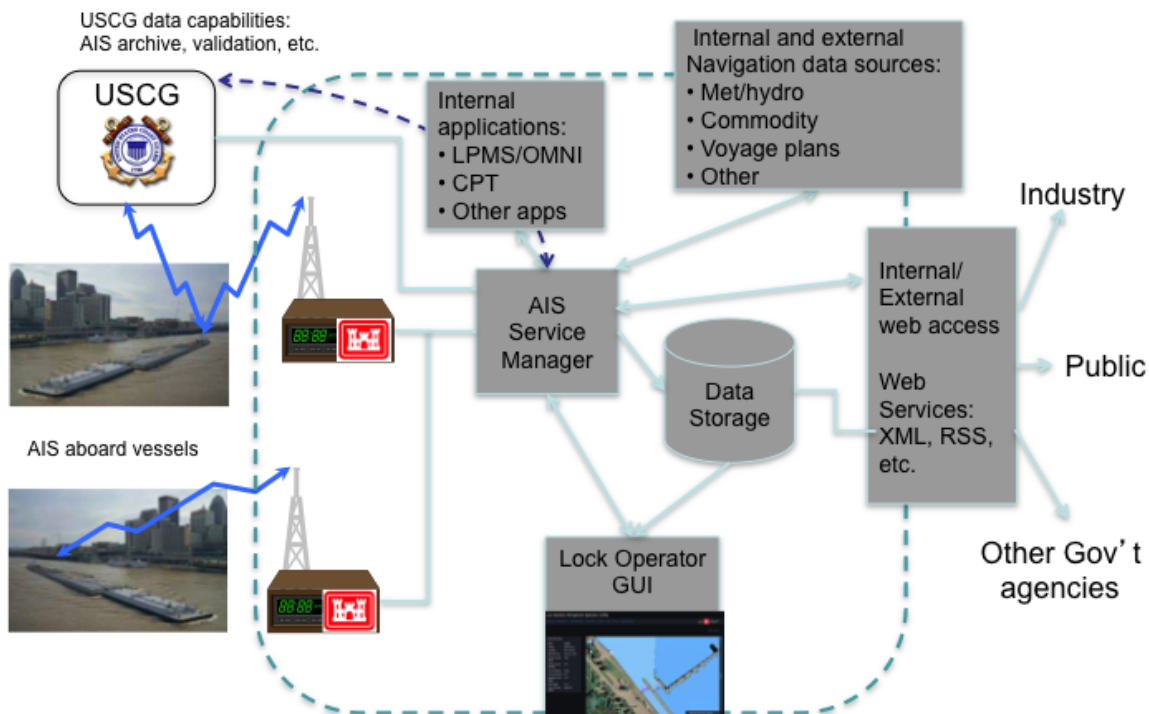


Figure 11. LOMA system overview.

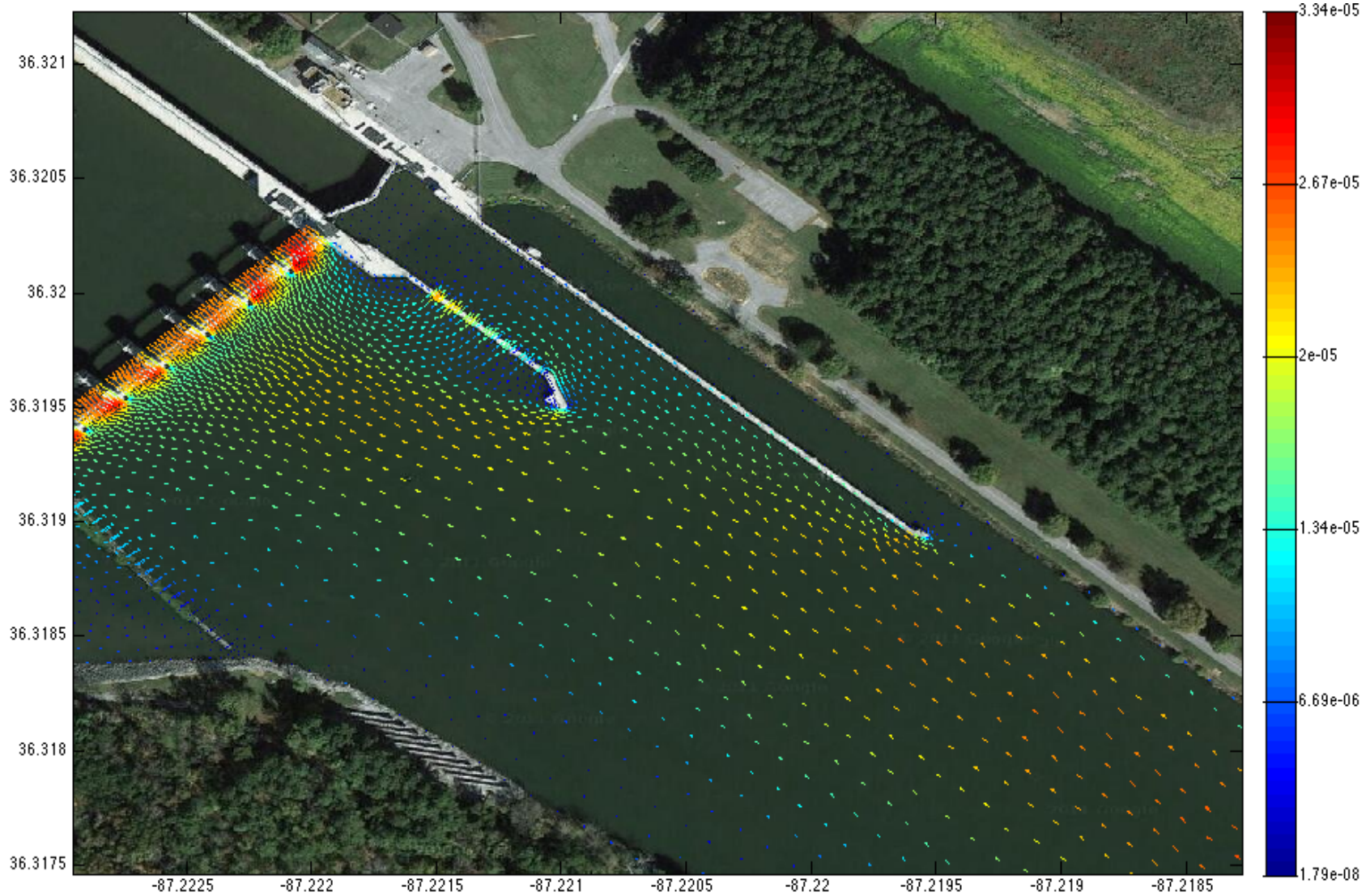


Figure 12. Sample lock current modeling output.



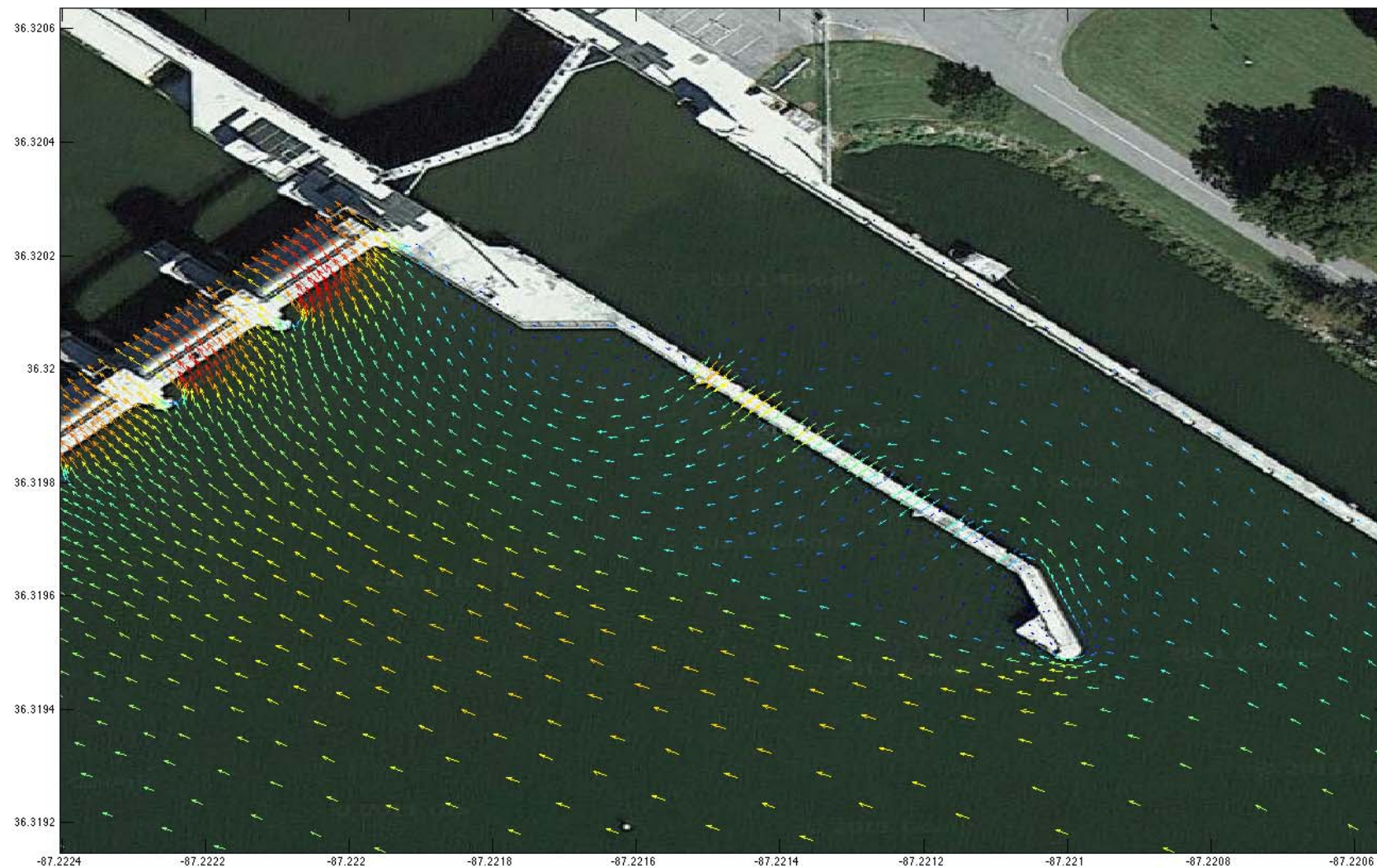


Figure 13. Close-up of Figure 12.



7 RECOMMENDATIONS

An AIS architecture that can support the dissemination of electronic Maritime Safety Information (eMIS), based upon international standards has been proposed by RDC. This architecture can support integration of PAWSS and NAIS. Many assumptions were made with regards to this proposed architecture and it's interfacing to PAWSS and NAIS. These assumptions will need to be evaluated and verified. Along with evaluating these assumptions, there is still considerable work remaining to be done to go from stand alone testing to a fully operational USCG capability. Without field testing on a larger scale, it is difficult to decide the best integration solution and architecture. The architecture described above proposes interfaces to allow transmission of all AIS message types; however, to date only message 8's have been tested. The rest of the transmit messages types will need to be tested as well.

A key component of the architecture is the AIS router. Some testing has been done on commercial options for this component, but only on a limited requirements set. Off-the-shelf solutions (i.e. Gatehouse, Kongsberg) should really be fully evaluated. This would help to define more fully the USCG requirements for this component and also develop acceptance tests.

This proposed architecture also needs to be expanded to define an appropriate regional-national hierarchy and interface details for integration with external agencies such as the USACE remain to be detailed. System monitoring is also a vital part of the overall system performance. A working group to investigate these issues should be formed with RDC involvement.

A transition plan to migrate from the current receive-only system to a full transmit-receive system also needs to be developed. Some NAIS Interim Receive components could be very useful in the final configuration, especially its monitoring and analysis capability, and should be evaluated. The working group to finalize the AIS architecture could also develop the transition plan.

With this type of capability, spiral development is highly recommended. Therefore, the working group should work closely with RDC for the implementation and testing of the architecture recommendations as they are developed.



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APPENDIX A AIS TRANSMIT PROJECT BACKGROUND

A.1 Background on AIS

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 and inland 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 locks and Aids to Navigation (AtoNs), and other port/waterway safety information.

While AIS is a highly effective means of providing information to a United States Coast Guard (USCG) Sector Command Center or Vessel Traffic Service (VTS) Center about vessel position and identification, it can also be used as a tool for communication by utilizing the transmit capability which includes both (1) broadcasts to all users within range and (2) addressed messages to specific users. Since 2007, USCG Research and Development Center (RDC) has been working to establish an AIS Transmit capability by identifying requirements, developing processes and procedures, and testing these processes and procedures in various AIS transmit test beds.

A.2 Background on AIS Transmit Project

The two primary goals of the USCG AIS Transmit initiative are (1) to reduce voice communications, and (2) to improve navigation safety and efficiency. This can be best achieved by meeting the following objectives:

- Identify and prioritize the types of information that should be broadcast using AIS binary messages (now referred to as Application Specific Messages (ASMs)): information that is available, important to the mariner, and provided to the mariner in a timely fashion and in a useable format.
- Develop recommendations for transmission architecture and shipboard display standards.
- Obtain data to support the goal of reduced voice communications and improved navigation.

To meet these objectives, the USCG VTS Program Office initiated the RDC AIS Transmit Project. There were three main tasks to this project:

1. Determine functional requirements. The goal is to establish what the AIS capability within a VTS should be. This involves identifying and gathering information from various AIS/VTS stakeholders. This is an iterative process throughout the project.
2. Establish test beds. The goal is to test concepts and ideas, draft standards, and validate requirements prior to USCG implementation by establishing test beds in existing VTS areas and encouraging active participation by maritime stakeholders.
3. Establish a Working Group within the Radio Technical Commission for Maritime Services (RTCM). The purpose of the Working Group is to review current VTS AIS capability in United States (U.S.) waters and recommend “consolidated” ASMs for regional and international implementation and to identify needed changes in AIS equipment to support new capabilities.



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The first task started with conducting a USCG Requirements Study in 2008 [13] that clearly showed there is a need and a desire to have more information flow from the VTS to the mariners as data rather than voice. There was also a clear need for flexibility in the information delivery, or more accurately, the ability to send the data that is needed, to the people who want it, based on area of operation. A review of the existing message types defined in International Maritime Organization (IMO) Safety of Navigation Circular (SN/Circ.) 236 [14] showed that they would not be useable to meet the information transfer needs of the maritime community.

These conclusions drove design considerations for the development and testing of ASMs. Phase I of the project focused on developing and testing an Environmental Message (EM) ASM to transmit environmental data (tides, currents, etc.). Phase II added a Geographic Notice (GN) ASM as well as support for demonstrations in Stellwagen Bank and the Columbia River. Phase III added a Waterways Management (WM) ASM and telecommands (used to send commands directly to the AIS radio onboard ships).

A.3 Test Beds

The AIS Transmit project's primary test bed is located in Tampa, FL. The project also expanded to include demonstrations and trials in the Stellwagen Bank, MA, Louisville, KY and the Columbia River, OR. This work has been reported on previously in [15-19] but is summarized in the sub-sections below.

A.3.1 Tampa Bay, FL

The Tampa VTS test bed was installed and commenced operation in September 2008; the site selection process and installation plan are documented in [20, 21]. The system diagram (Figure) shows the processes (colored blocks) and the locations where they are running (colored clouds). The Fetcher/Formatter (FF), Queue Manager (QM) and ARI are software programs running on a computer at RDC and monitored by Alion. The ASMs are sent to the AIS base station in Largo, FL that is shared with the VTS operations system (Norcontrol™ software by Kongsberg). The Nationwide AIS (NAIS) receiver at Palmetto is used as the monitor site and to calculate VHF Data Link (VDL) loading using Internet Protocol to Communication Port Conversion Software, IP2COMM, (both AIS User and IP2COMM are also running on the QM computer). Figure shows the locations of the base station (upper left) and the receiver (lower right) relative to Tampa Bay. Alion and VTS personnel are monitoring the overall system performance to ensure that the data is getting to the users. Transview (see Figure A-3), ASM Decoder (see Figure A-4), and ARINC's PilotMate™ software are used both at RDC and the VTS to monitor operations. Transview in conjunction with VTS Info Manager is used at the VTS to create Geographic Notice messages.



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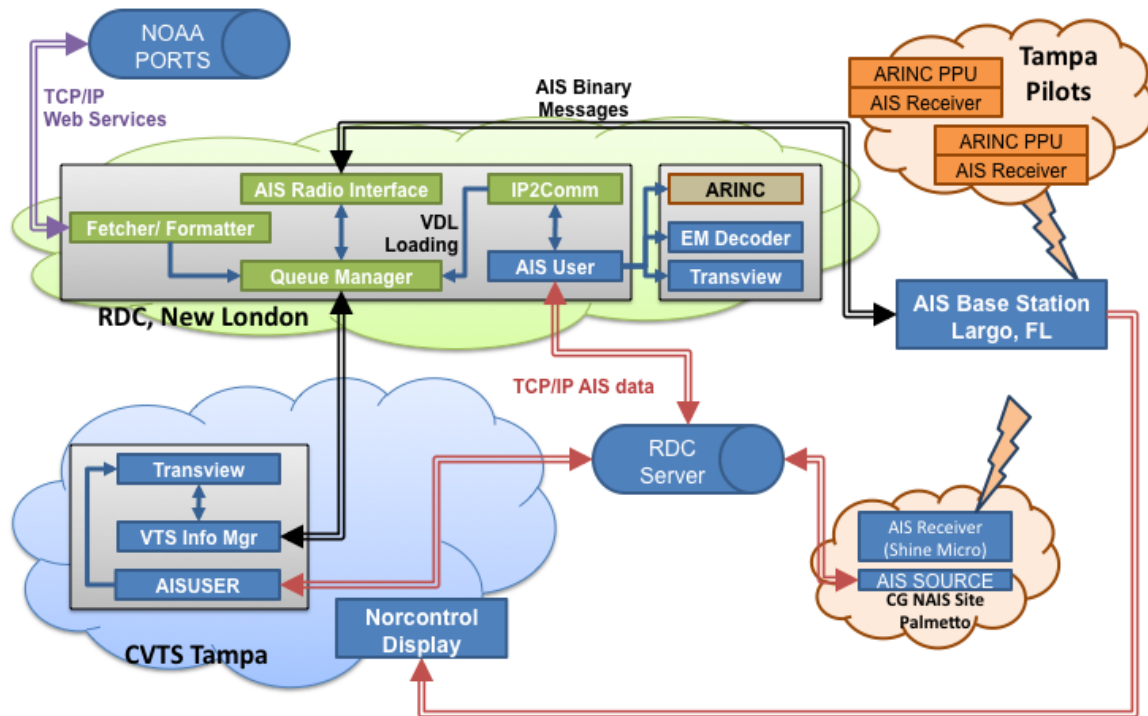


Figure A-1. Current state of VTS Tampa test bed.

(Grey boxes are computers, blue boxes represent government software, databases, or equipment, green boxes are Alion-developed software, and orange boxes are COTS software and equipment.)

Stakeholder Feedback:

- The Tampa Bay Pilots and VTS (USCG and Port Authority) have been very supportive partners. The test bed personnel are able to create and deliver binary message, which mariners can use aboard ship. This information provides the pilots with better situational awareness of met/hydro conditions in the port area and has been used for decision support (go/no-go decisions).
- Physical Oceanographic Real-Time System (PORTS) data is sent using the ASM. Pilots preferred receiving the PORTS data through the AIS broadcast vs. phone or Internet.
- The Tampa Pilots also preferred the text display of the data to a graphical display on their Portable Pilot Units (PPUs).

The Tampa test bed has been the primary test site to evaluate processes and performance for future implementation at all Coast Guard VTS sites. The testing done in Tampa has enabled an understanding of the transmit process and driven the development of the proposed transmit architecture.





Figure A-2. Tampa transmitter and receiver sites.



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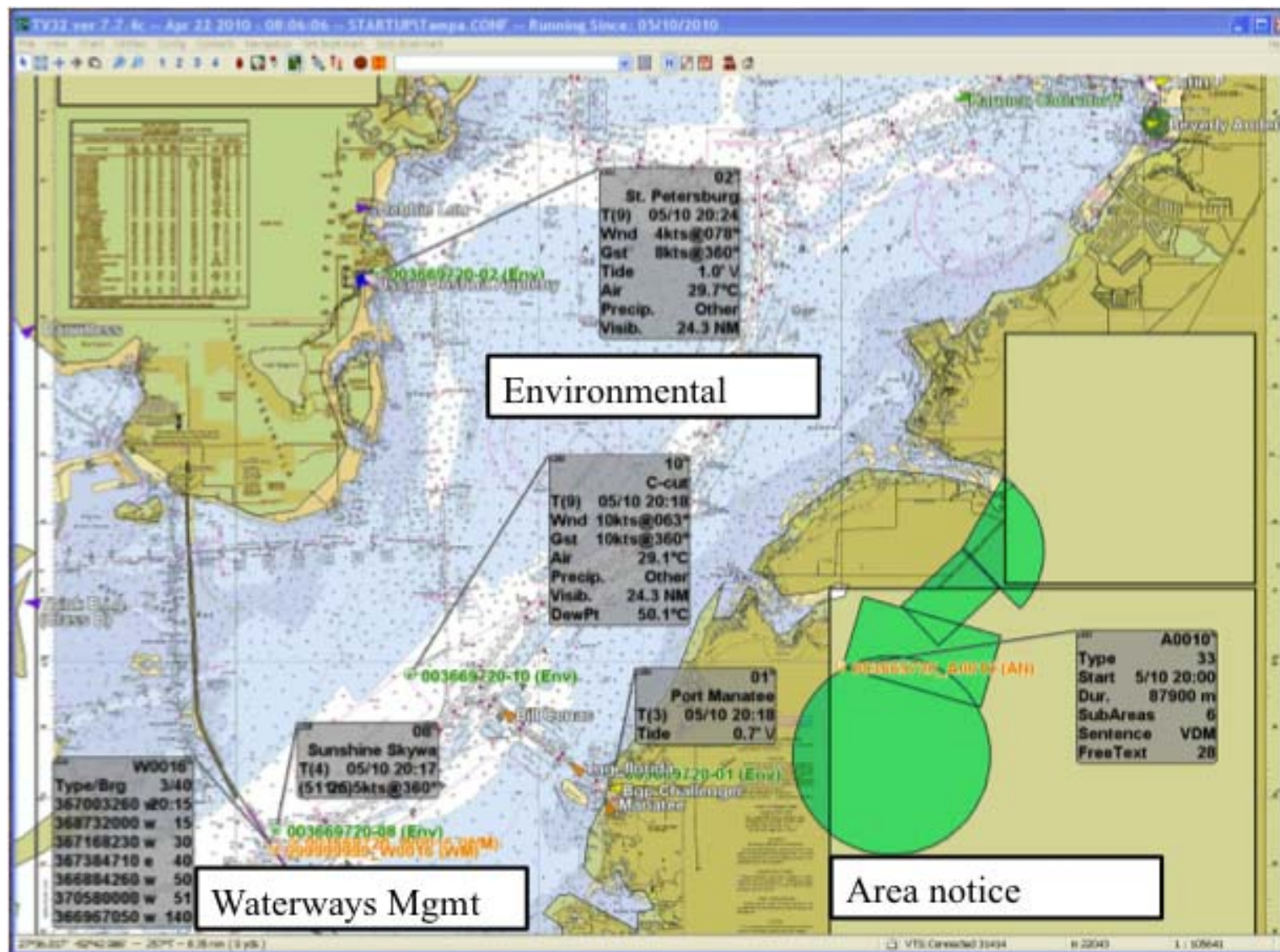


Figure A-3. Sample transview (TV32) display. Change above to geographic notice.



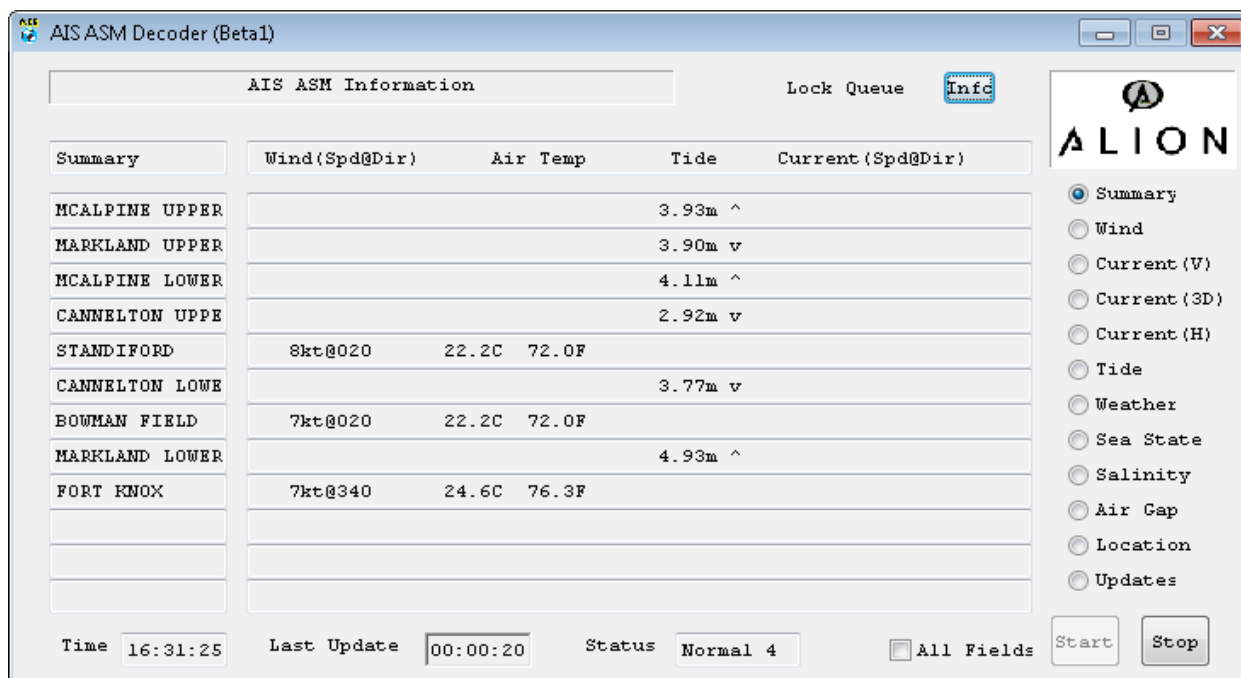


Figure A-4. AIS ASM message decoder GUI.

A.3.2 Stellwagen Bank

The Stellwagen Bank demonstration has been a joint effort between the RDC and National Oceanic and Atmospheric Administration (NOAA) National Marine Sanctuary (NMS)(with University of New Hampshire (UNH) and Cornell University support). The location of this test bed is shown in Figure A-5. The goal of this effort is to broadcast via AIS an indication of the presence or absence of right whales in the vicinity of the 10 acoustic monitoring buoys so that ships can slow down if there are whales in the area. An overview of the demonstration set-up is shown in Figure A-6. The AIS broadcast portion of the demonstration commenced operation in September 2008. The user equipment side (NMS/UNH responsibility) started operation in earnest with an iPad application (WhaleAlert) in 2012. NOAA NMS is the overall lead for this effort. Cornell is responsible for the operation of the acoustic buoys. They receive the acoustic signature data from the buoys via an Iridium satellite link and process it at Cornell to determine if right whales are present or not. This information goes into their database where it can be accessed and viewed over the Internet. UNH provides software support and wrote the code that retrieves the right whale data from Cornell's database and provides Geographic Notices to the Right Whale Queue Manager (this is the equivalent of the Fetcher/Formatter used for Tampa).

The FF and QM are currently being run at Cornell and monitored by UNH (both under contract to NOAA). The ARI software is running on a computer at Provincetown and provides the interface to the AIS AtoN transmitter (this was substituted for the original base station in Jan 2011). The NAIS receivers in the Boston area are used as monitor sites. Alion and UNH are monitoring the overall system performance to ensure that the data is getting to the users.



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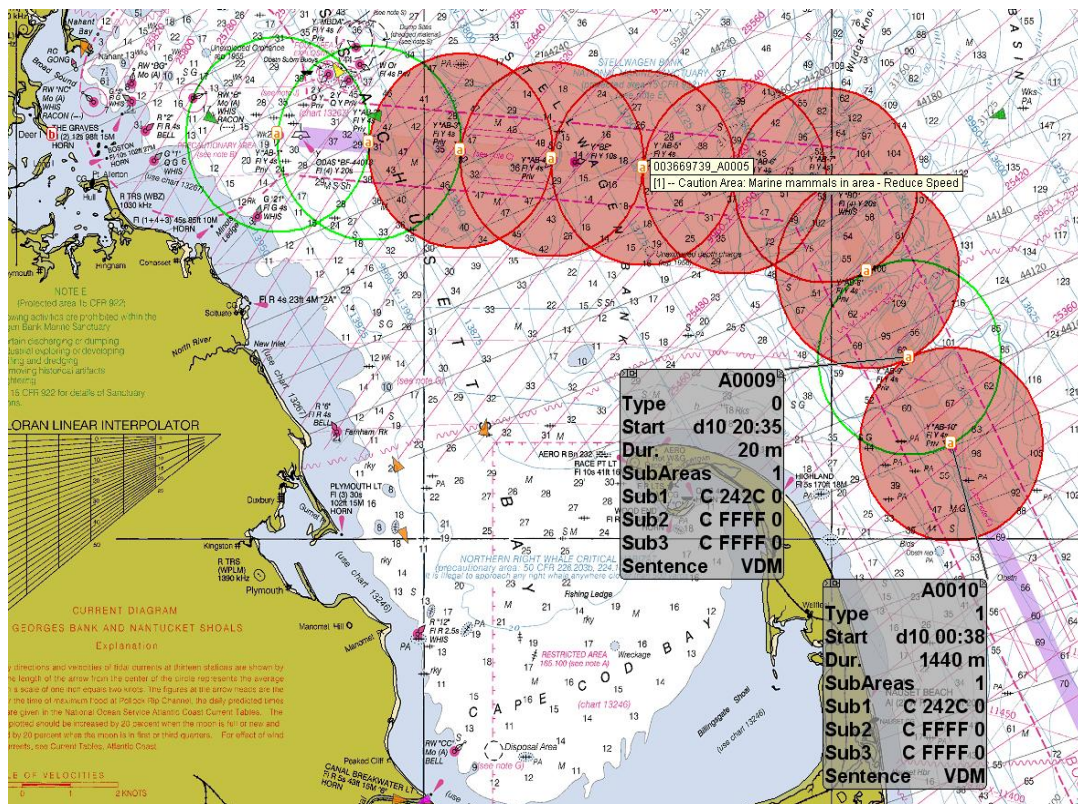


Figure A-5. Stellwagen Bank demonstration area.
(Red circles indicate whales present; green circles indicate no whales detected.)

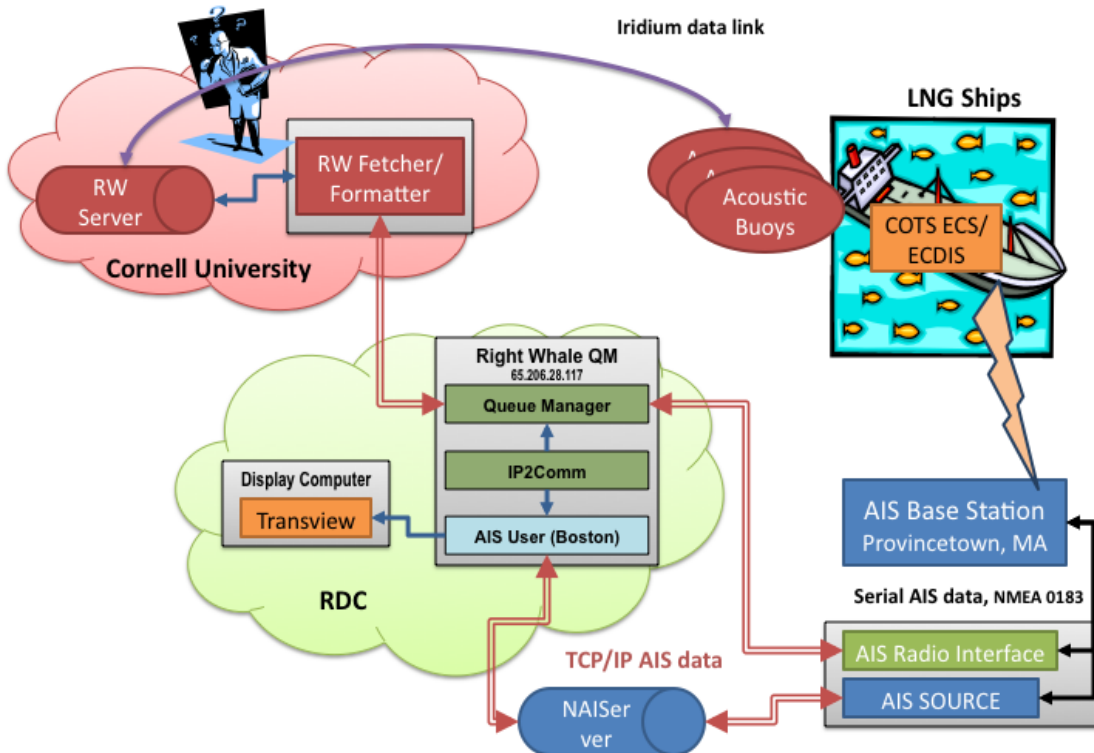


Figure A-6. Stellwagen Bank demonstration architecture.



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A.3.3 Columbia River

The Columbia River Demonstration has been a joint effort between the RDC and the Columbia River Pilots (COLRIP). A system diagram is shown in Figure A-7. The AIS base stations (Green Mountain and Meglar Mountain) are operated/monitored for the COLRIP by the Department of Transportation, Volpe Center. The two base stations are operated in repeater mode so that all traffic received is retransmitted. Originally, the FF, QM and ARI were running on a computer at RDC and monitored by Alion. The Volpe Center has since taken over the AIS transmit operations in the Columbia River (as of Aug 2010) as part of their contracted support to the COLRIP. To enable this transition, the FF, QM, and ARI processes were moved to the COLRIP office and are now monitored by Volpe along with the Transview (TV32) installation that is there now. COLRIP and Volpe are responsible for monitoring system performance and VDL loading using data feeds from the two transmitter sites. RDC conducts monitoring on an ad hoc basis using the NAIS receiver at Cape Disappointment. TV32 and ASM Decoder software are used at RDC to monitor operations. A chart showing relative positions of the transmitters/receiver is shown in Figure A-8.

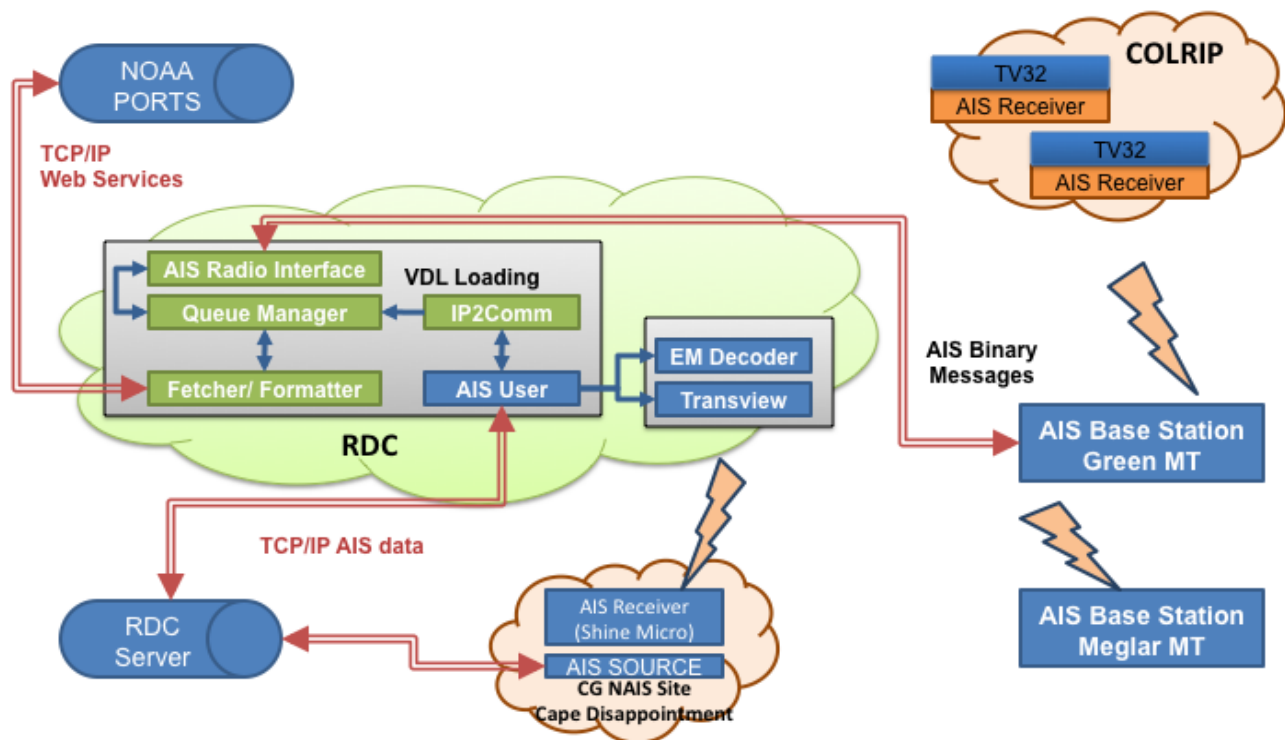


Figure A-7. Columbia River demonstration system diagram.



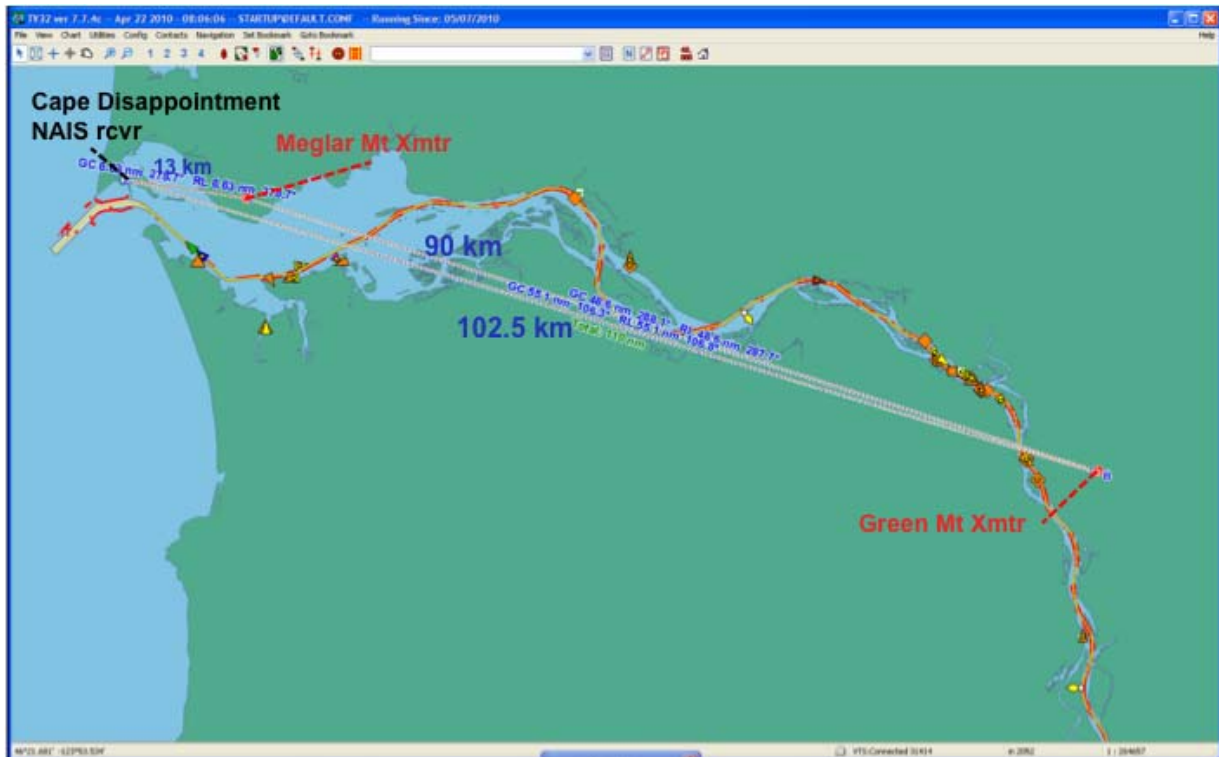


Figure A-8. Columbia River demonstration diagram showing transmitter locations.

Colombia River Results/stakeholder feedback:

- The Columbia River Pilots actively use the environmental data as part of their operations.
- They use TV32 as their Personal Pilot Units and like the geographically tied text display.
- The test bed with two transmitters in a repeater mode provided RDC with some valuable experience in repeater operation and VDL impacts. This is documented in [9].

A.3.4 Louisville, KY

VTC Louisville is a unique Vessel Traffic Center (VTC) with non-traditional VTC operational requirements. VTC Watchstanders are only required to "stand up" when the Ohio River crests above 13 feet. Due to the infrequency of this event, typical VTC sensors and hardware systems are not installed. Operators rely primarily on a network of five cameras and a standard radio system. To aid watchstanders during operational events and to increase everyday maritime domain awareness in the VTC Area of Responsibility (AOR), VTC Louisville recently added AIS capability.

A test bed was established in Louisville in 2011 (see Figure A-9) for multiple reasons. First, Louisville would be the first test bed to be established inland, away from a major port. Second, it had limited line of sight VHF signal paths due to winding rivers, land mass obstructions and heavy foliage, conditions not encountered in a typical coastal port. Third, it was the first test bed where PORTS data is not available. And finally, it was a VTS that had a lock in the AOR. The goals for this test bed were:

- Develop and test new sources of environmental data for transmission such as river current sensors and river gauge sensors.
- Test the usage of the WM ASMs and assess their usefulness.

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- Develop and test the automatic generation of WM ASMs from USACE data sources (vessels awaiting lockage).
- Test the usage of the Synthetic/VTIS Target ASM.
- Test the usage of Telecommands and assess their usefulness.
- Test AIS Transmit effectiveness for inland waterways environments.
- Assess the benefits of Enhanced AIS for inland waterways vessel traffic management.

This test bed was also the first to be set up using the new transmit architecture and processes. Although this provided a good test bed for developing the new architecture software, of the 7 goals listed, only some were met during the Phase I test. Specifically, goals 1 and 3 were met; message encoders were developed to pull data from USACE (flow and gauge), from National Weather Service (NWS) (airport weather), and from storm warning database. Vessels queue information from three locks (McAlpine, Cannelton, and Markland) was also transmitted (see Figure A-10). Goal number 2 could not be met as the user software was never completed by Channel ECDIS and Course Trajectory (CEACT) navigation software, so although messages were being transmitted, they were not decoded and displayed. CEACT is navigation software used by some vessels on the Ohio River. Goals 4 and 5 were not done due to insufficient time and lack of user software support. Goals 6 and 7 could not be fully assessed due to the lack of user software.

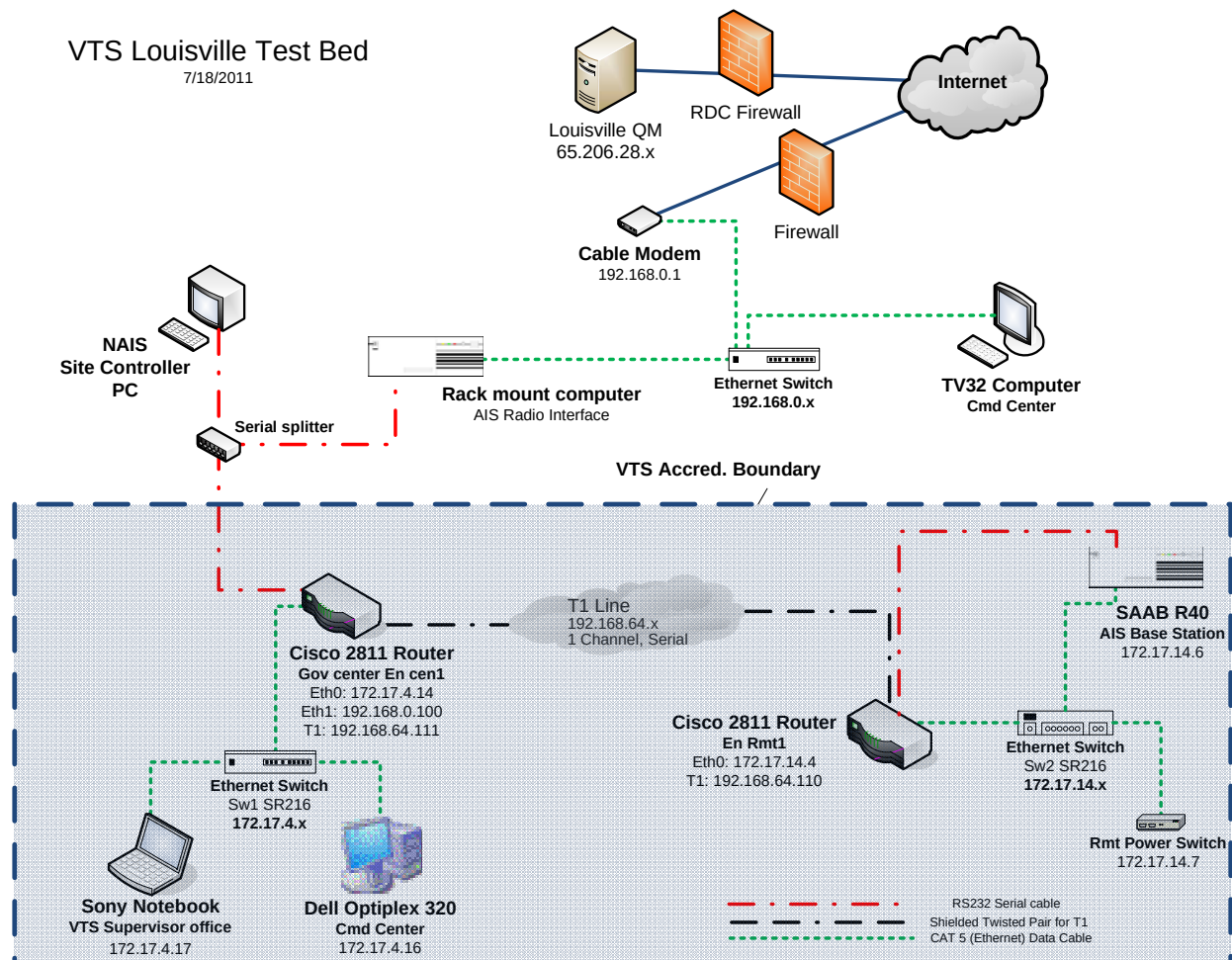


Figure A-9. Louisville test bed architecture.

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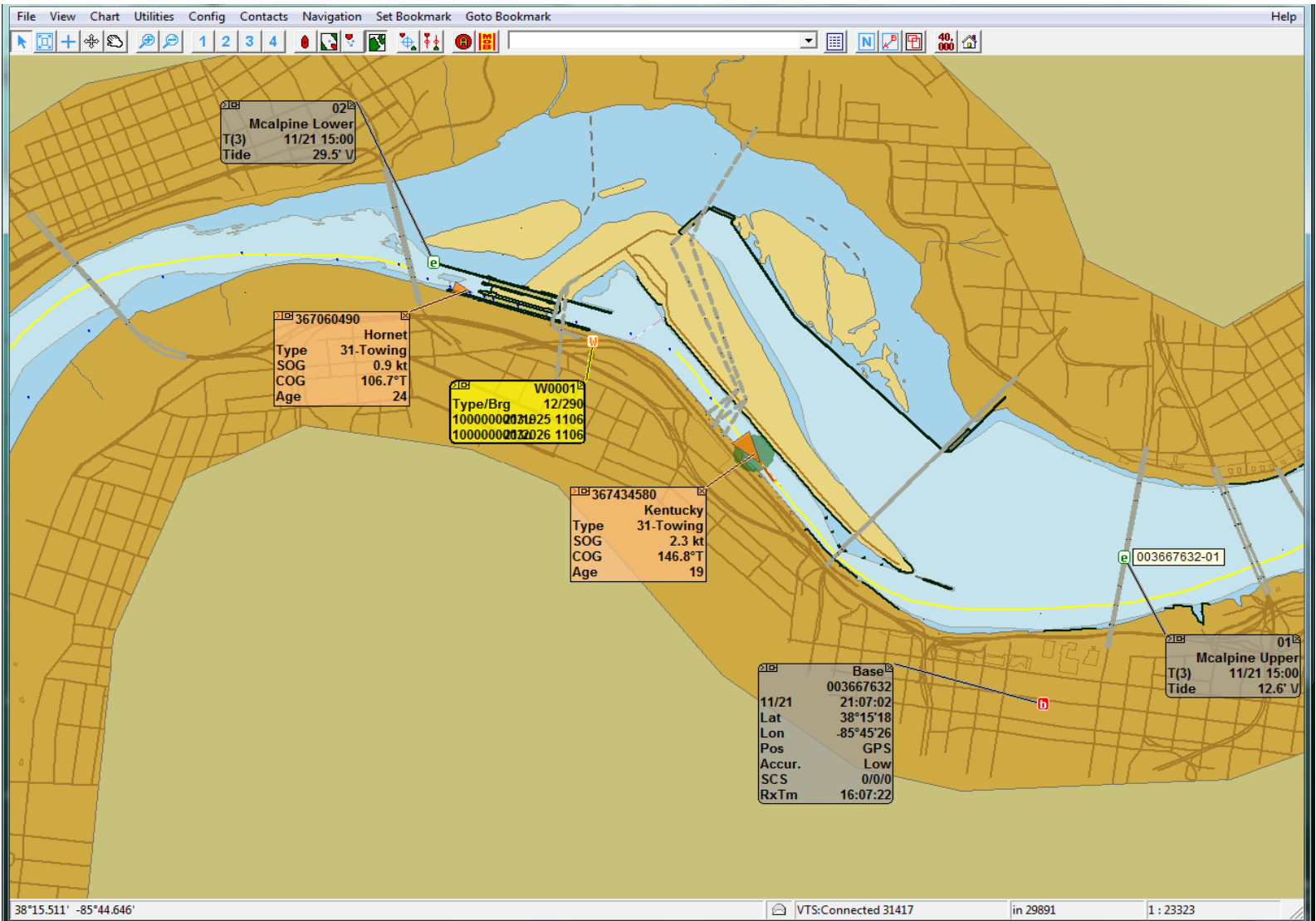


Figure A-10. Louisville test bed TV32 display showing environmental data, lock queue information, and vessels.

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In order to complete the assessment processes, the decision was made to conduct a Phase II test at Louisville. The goals of the second phase are to:

- Fully test the Waterways Management Message and assess its usefulness from the mariner's point of view.
- Assess the Integration/Management of AIS AtoN into the transmit architecture.
- (Optional) Test the Telecommands.

The start of the Phase 2 test bed is contingent upon several work items:

- Final approval of AIS ASM messages and their incorporation into the user software. Completed in May/June 2013.
- Repair, relocation or replacement of the Acoustic Doppler Current Profiler at Louisville in order to provide a source of current data. This is in-progress and expected to be complete OOA 1 July 2013.
- Addition of a weather sensor to provide local wind speeds. Completed – weather station is being placed at the lock.
- USACE must restore the lock queue information accessibility (due to a changeover in the USACE systems, the data source previously used is no longer available). Completed - functionality for lock queue is now available through the new system.
- Approval of a new Interim Authority To Test (IATT). Approved for 180-day period starting July 1, 2013.

Since the work items have been completed or are projected to be complete, the Phase 2 test is scheduled to start on 1 July 2013.

