Naval Information Warfare Center

PACIFIC

TECHNICAL REPORT 3276

MAY 2022

Chat Over Automatic Identification System (AIS) Test Results

Lynne A. Tablewski

NIWC Pacific

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Naval Information Warfare Center Pacific (NIWC Pacific)

San Diego, CA 92152-5001

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EXECUTIVE SUMMARY

The Chat Over Automatic Identification System (AIS) allows vessels to communicate between vessels and from vessels to land sites such as a Maritime Orientation Center (MOC). Naval Forces Africa (NAVAF) provided funding to test Chat Over AIS (COA) at sea during AFRICOM's OBANGAME Express. However, due to the Covid-19 pandemic COA could not be tested in Africa. As an alternative, COA testing took place off the Southern California (SOCAL) coast.

OBJECTIVE

1. The purpose of the COA test was to demonstrate that vessels are able to send and receive direct AIS text messages[1]. If a message is received, then the receiving hardware automatically sends an acknowledgement message. The author has observed frustrated VHF radio operators at MOCs trying to hail their Navy vessels. As a result, the COA system also provides the capability for text messages to be resent automatically until an automatic message is received.
2. Based on the author's observations during OBGAME Express, the COA system also provides Naval vessels the capability to transmit their AIS GPS locations back to a MOC. Naval vessels normally do not transmit their GPS location; therefore, the MOC operators do not know their location. The COA system uses an Aid to Navigation (AtoN) AIS Transponder, which does not send out the standard AIS position reports since it was designed for sending data.
3. Finally, the COA system allows vessels to automatically send a SeaVision[2] (SV) Manual Report[3] directly to SV.

METHODS

COA testing occurred on September 20, 22 and 23 off of SOCAL coast and consisted of the following: two vessels (Polaris and Vessel Two), a coastal MOC, and an AIS repeater station located on Mount Soledad. Figure 1 represents the test area with the small blue circle representing the estimated Line of Sight (LOS) from the MOC (11 nm) and the larger orange circle the estimated LOS from the MOC using Mount Soledad as an AIS repeater to extend the range between the MOC and Polaris to 35 nm.

Testing involved having the Polaris sail beyond both circles for a limited time period. Vessel Two was a vessel of convenience for the COA test; therefore, its route was not controlled for this test. Although Vessel Two's COA system was not continuously manned, it did have an individual who would occasionally chat with the MOC and the Polaris.

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1 The AIS standard allows Class A AIS Transponders to send text messages to Class A or Class B Transponders; however, the user interface to send a text is not intuitive.

2 SeaVision provides a web-based unclassified maritime information sharing and management environment that enables both Public Key Infrastructure (PKI) and non-PKI users to share a broad array of unclassified maritime information to increase maritime security and build partnerships within the maritime community.

3 Manual Reports allows you to report the location of a vessel or incident to display on the map.

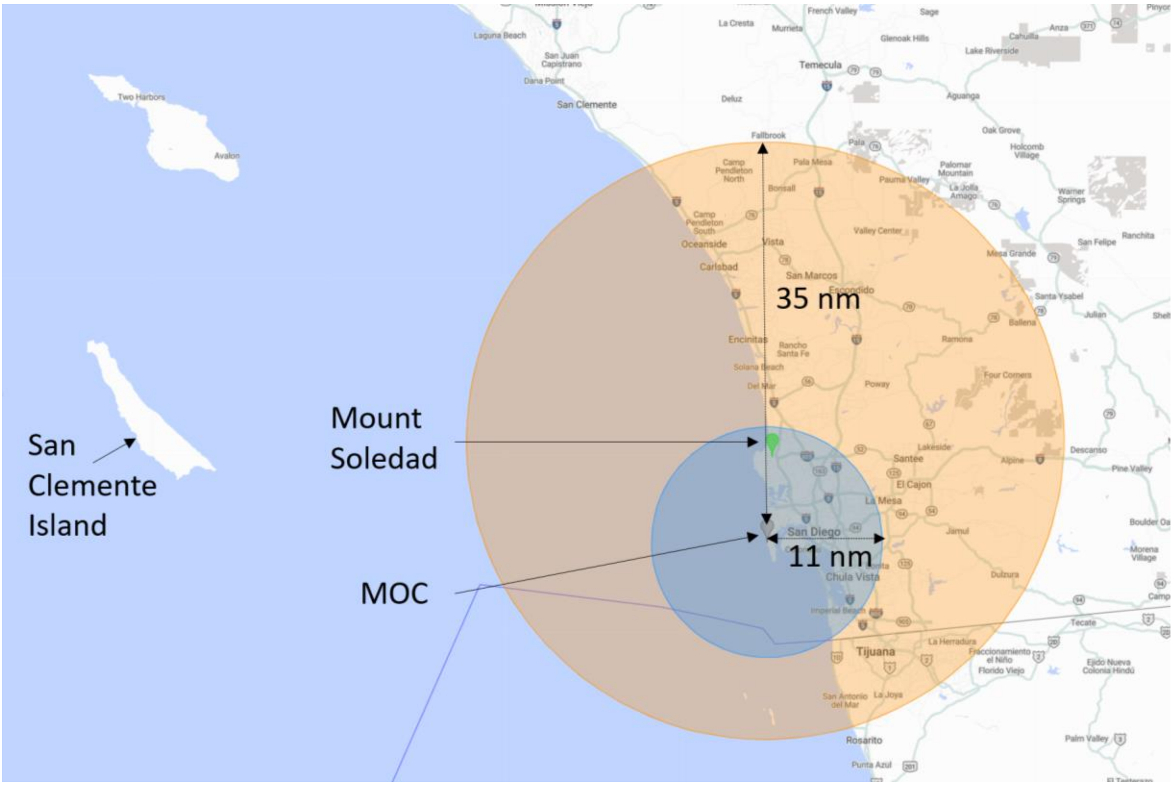

Figure 1. SOCAL Area of Test Operations.

Objective 1 To confirm message acknowledgement and message resending capabilities. Ship riders aboard the Polaris and Vessel Two exchanged text message with the MOC operator when vessels were within and outside LOS.

Objective 2 The MOC operator used the receipt of the GPS position data as a confirmation that a vessel was within LOS. Both the Polaris and Vessel Two automatically sent their GPS position data over AIS to the MOC's COA system.

Objective 3 A ship rider aboard the Polaris sent Manual Reports (MR) using COA interface and the MOC operator checked SV to confirm if a MR automatically displayed in SV.

CONCLUSIONS AND RECOMMENDATIONS

The COA capabilities were tested over three days of testing. Based on test results the following modifications are recommended for COA:

- Reduce the GPS and MR message packet sizes so this data can be sent as one AIS message instead of three for each of these messages. Reducing the number of AIS packets required to send either a GPS or MR messages will increase the probability that these messages will be received correctly when transmitted.
- Provide a better user interface for MR. A new interface should automatically populate position fields, time, date and allow a user to have a pull-down option to select a reason for the MR or allow user to their own text. The current method for MR is very cumbersome which can lead to operator error.

Overall, users aboard the vessels and at the MOC were happy with the COA interface design and the ease of use. A merchant marine aboard Vessel Two commented on how this capability was needed to easily communicate if vessels near them needed assistance when outside cell phone ranges. COA is a capability that benefits areas where VHF radio operators have difficulty understanding each other due to language. They could follow up a radio conversation with a COA text to verify information that may be difficult to relay over voice.

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ACRONYMS

AIS	Automatic Identification System
AFRICOM	United Stated Africa Command
AtoN	Aid to Navigation
COA	Chat Over AIS
GPS	Global Position System
LOS	Line of Sight
MABL	Marine Atmospheric Boundary Layer
M	Meter
MMSI	Maritime Mobile Service Identity
MOC	Maritime Operation Center
MR	Manual Report
NAVAF	Naval Forces Africa
NM	Nautical Miles
OBANGAME	OBANGAME Express Exercise
PKI	Public Key Infrastructure
RF	Radio Frequency
ROA	RADAR over AIS
SOCAL	Southern California
SV	SeaVision
VHF	Very High Frequency

CONTENTS

FIGURES

1. INTRODUCTION

Chat Over AIS (COA) provides a user-friendly "Rocket Chat"[4] interface which allows users to communicate by text using Automatic Identification System (AIS) message type 6. AIS message type 6 was designed to allow users to send and receive direct messages using their vessel's Maritime Mobile Service Identity (MMSI) number. In addition to providing an improved user interface, COA provides re-transmission of a text message if the vessel is not within Radio Frequency (RF) Line of Sight (LOS) range. For example, if a sender's vessel is not within LOS of the receiving vessel, then the sender's messages are periodically resent until the receiving vessel is within LOS.

COA also provides the capability to send GPS messages via text which allows Navy vessels to report their positions to their Maritime Organization Center (MOC) if the vessel does not want to transmit their position to surrounding vessels. COA utilizes an Aide to Navigation (AtoN) which is designed for data transmission and not vessel collision avoidance. Standard Class A or Class B AIS Transponders are designed for collision avoidance and they will automatically report a vessel's position.

In addition, vessels will be able to automatically send a Manual Report Event into the SeaVision (SV) Website. Adding the event automatically to SV allows MOC operators to see the Manual Report and then act on this information.

1.1 PURPOSE

Naval Forces Africa (NAVAF) provided funding to test COA at sea during AFRICOM's OBANGAME Express but due to the Covid-19 pandemic the system could not be tested in Africa. As an alternative, COA testing occurred off the Southern California (SOCAL) coast on September 20, 22 and 23, 2021. The purpose of the sea test was to test the following COA capabilities:

- Demonstrate that vessels were able to send and receive direct AIS text messages. If a message was received, then the receiving hardware automatically sends an acknowledgement message.
- Resend text message automatically until an automatic acknowledgement message is received.
- Transmit a vessel's GPS locations back to a MOC.
- Allow vessel COA's operators to automatically inject a SV Manual Report.

1.1.1 Sea Test Requirement

COA testing required testing between vessel to vessel and shore to vessel communications. Therefore, COA testing enlisted two vessels, the Polaris (Figure 2) Vessel Two for vessel to vessel testing.

[4] Rocket.Chat is an open-source fully customizable communications platform developed in JavaScript for organizations with high standards of data protection. https://github.com/RocketChat/Rocket.Chat

Figure 2. Polaris with COA Operator.

COA utilized two shore locations. One site acted as a MOC with two primary purposes: to have a MOC user communicate using COA with both vessels and to receive a vessel's GPS position data. The MOC location also required internet connectivity to allow the COA software to send the vessel's SV Manual Reports directly to SV's API.

The second shore location was set up with an AtoN to extend the RF LOS between the Polaris and the MOC by repeating the AIS type 6 messages. Unlike other AIS transponders, the AtoN has the capability to act as AIS message repeater. This capability has been used in the past to extend another system, RADAR Over AIS (ROA), but had never been tested using COA.

1.1.1.1 MOC Shore Location

Naval Information Warfare Center (NIWC) Propagation Branch bldg. 323 was chosen as the MOC location due to its location facing the Pacific Ocean - it is the primary testing location for the ROA system, and the building has WIFI connectivity. The AtoN's antenna was installed at 27 m above sea level. If we assume atmospheric propagation using Equation 1

$$d1 = \sqrt{2 * {}^{4}/_{3} * R * AntHeight + \ AntHeight^2}$$

Equation 1 RF LOS

with R the earth's radius, and the antenna height of 27 m then the RF LOS distance = 21 km or 11 nm. Figure 3 shows the estimated RF line of sight distance from MOC (small circle).

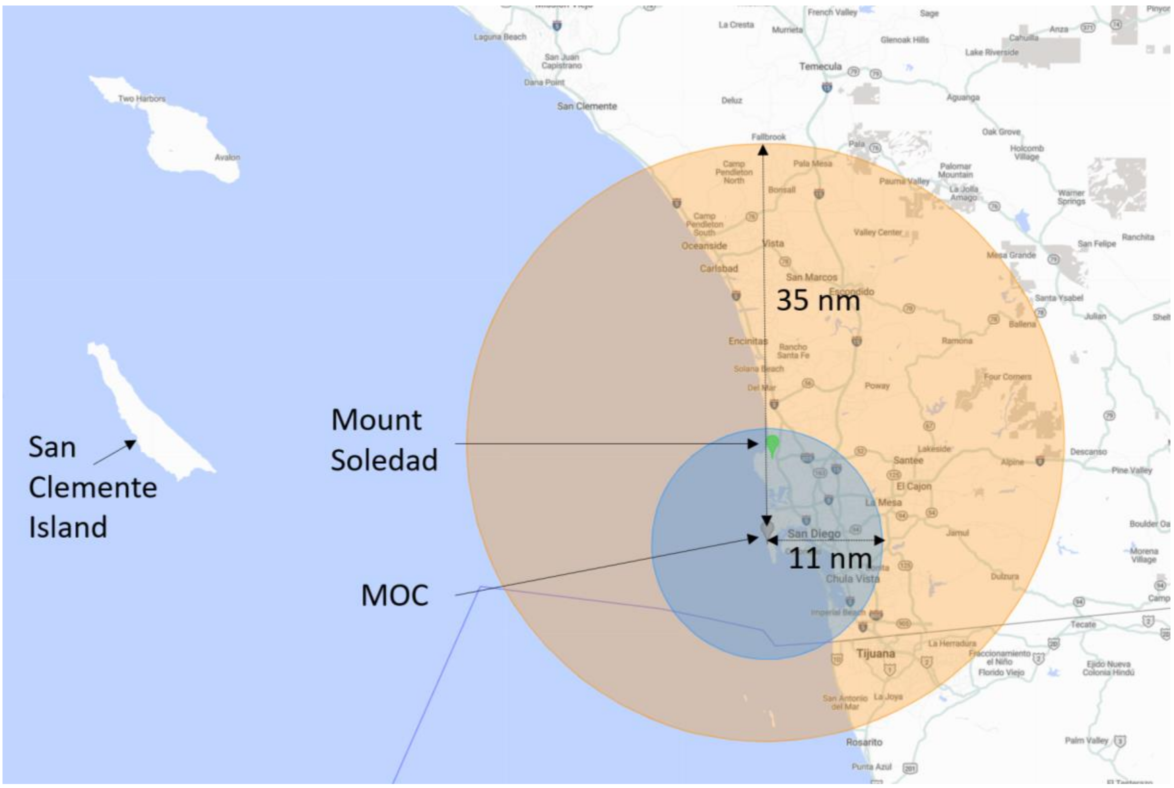

Figure 3. RF LOS from MOC.

Mount Soledad, Figure 3, was chosen for the location of the AtoN AIS repeater location in order to extend RF line of sight coverage and between the MOC and the Polaris. Using Equation 1 the AIS repeater could extend RF LOS to 35 nm from the MOC.

1.1.1.2 At Sea Locations

The primary COA vessel, Polaris, was contracted out to support COA and ROA testing. The Polaris crew consisted of a coxswain, ROA operator and a COA operator. The Polaris transited within the two circles in Figure 3 for two of the three days of testing. On the last day of testing the Polaris travelled beyond the 35 nm in order to test the ROA system.

Vessel Two was the secondary COA vessel. Vessel Two transited between Point Loma and San Clemente Island from September 20 – 30. The COA system was unmanned but it sent its GPS coordinates back to the MOC and occasionally a ship operator sent COA messages to either the MOC or the Polaris.

1.2 DAY 1: SEPTEMBER 20, 2021

1.2.1 Purpose

- Polaris stayed within shore to maintain cell phone connectivity.
- Test COA software
  - When within LOS of MOC
  - When vessel is not within LOS of MOC
  - Using AIS repeater mounted on Mount Soledad

1.2.2 Results:

1.2.2.1 GPS Transmitted & Received AIS Type Messages

Figure 4 is a plot of the GPS automatically sent from the Polaris (red dots) to the MOC (green dots) using the COA text messages prior to turning on the AtoN AIS repeater located on Mount Soledad. The MOC was able to receive the Polaris for 9 nm before the vessel was out of LOS at 10 nm which was less than the theoretical 11 nm range. Note that the COA system was temporarily turned off at the MOC which is called out in Figure 4.

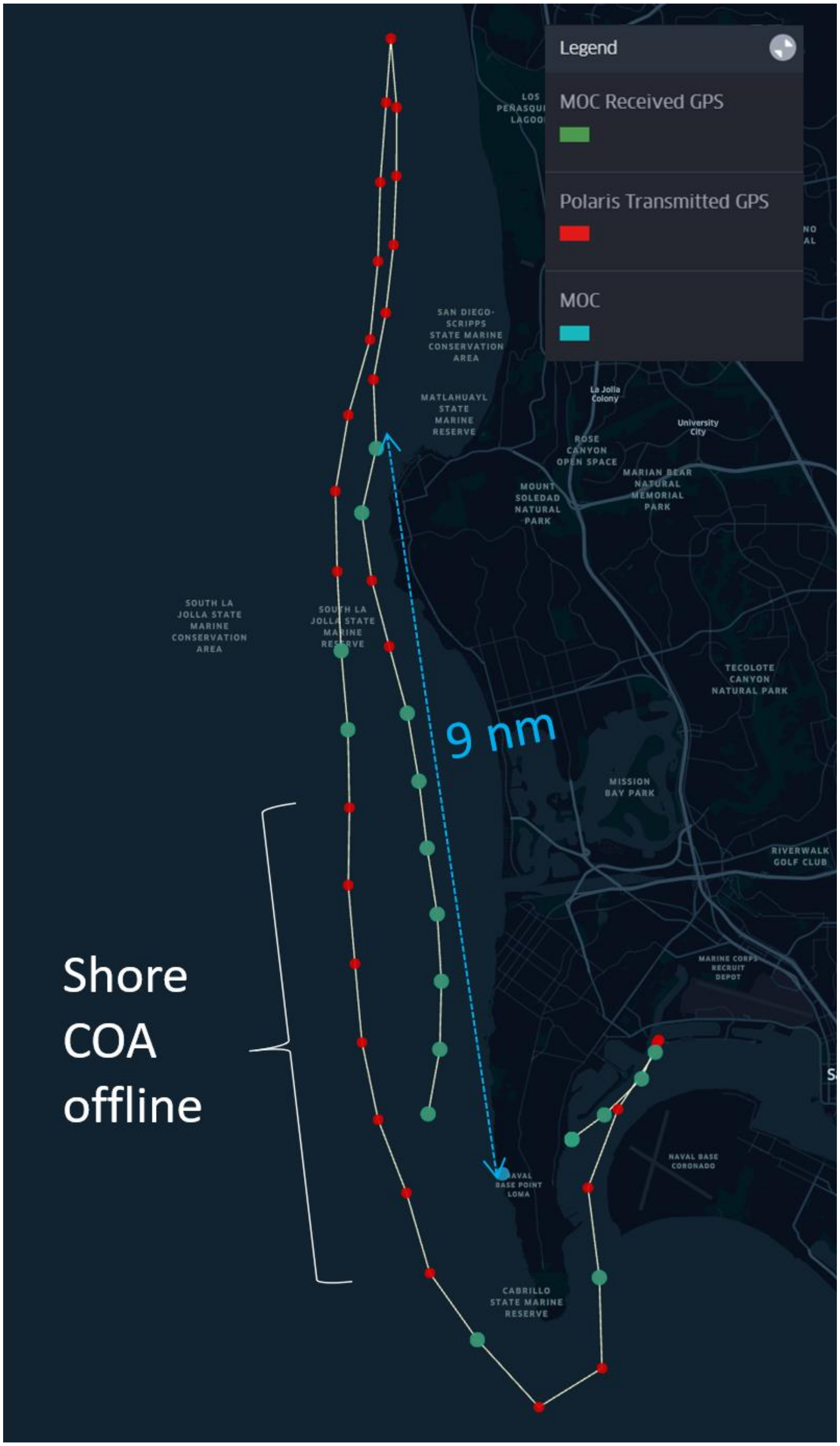

Figure 4. Day 1: GPS Sent from Polaris and Received by MOC.

Worth nothing is that at the beginning the vessel transmitted to a fuel dock and the majority of the GPS data was not received at the MOC due to elevation obstruction which is shown in Figure 5.

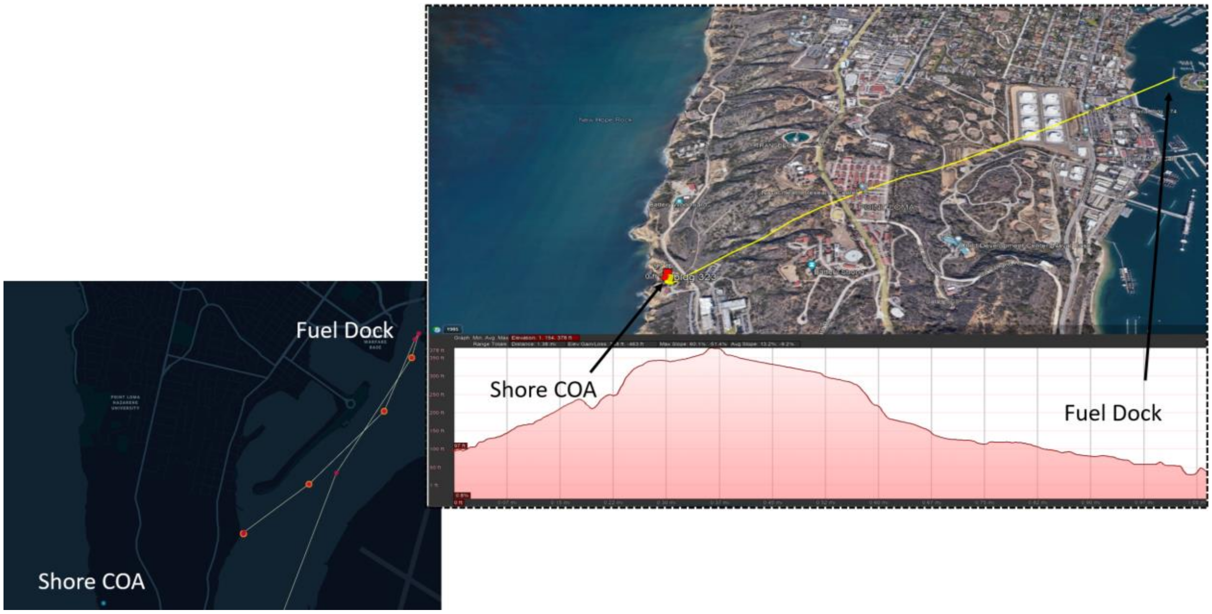

Figure 5. Elevation Obstruction between MOC & Polaris at Fuel Dock.

Figure 6 is similar to Figure 4 except the AtoN repeater was turned on for message type 6 during the transmission of the Polaris GPS data. The AIS repeating did provide an increase of range to 14 nm from the MOC but it was not consistent.

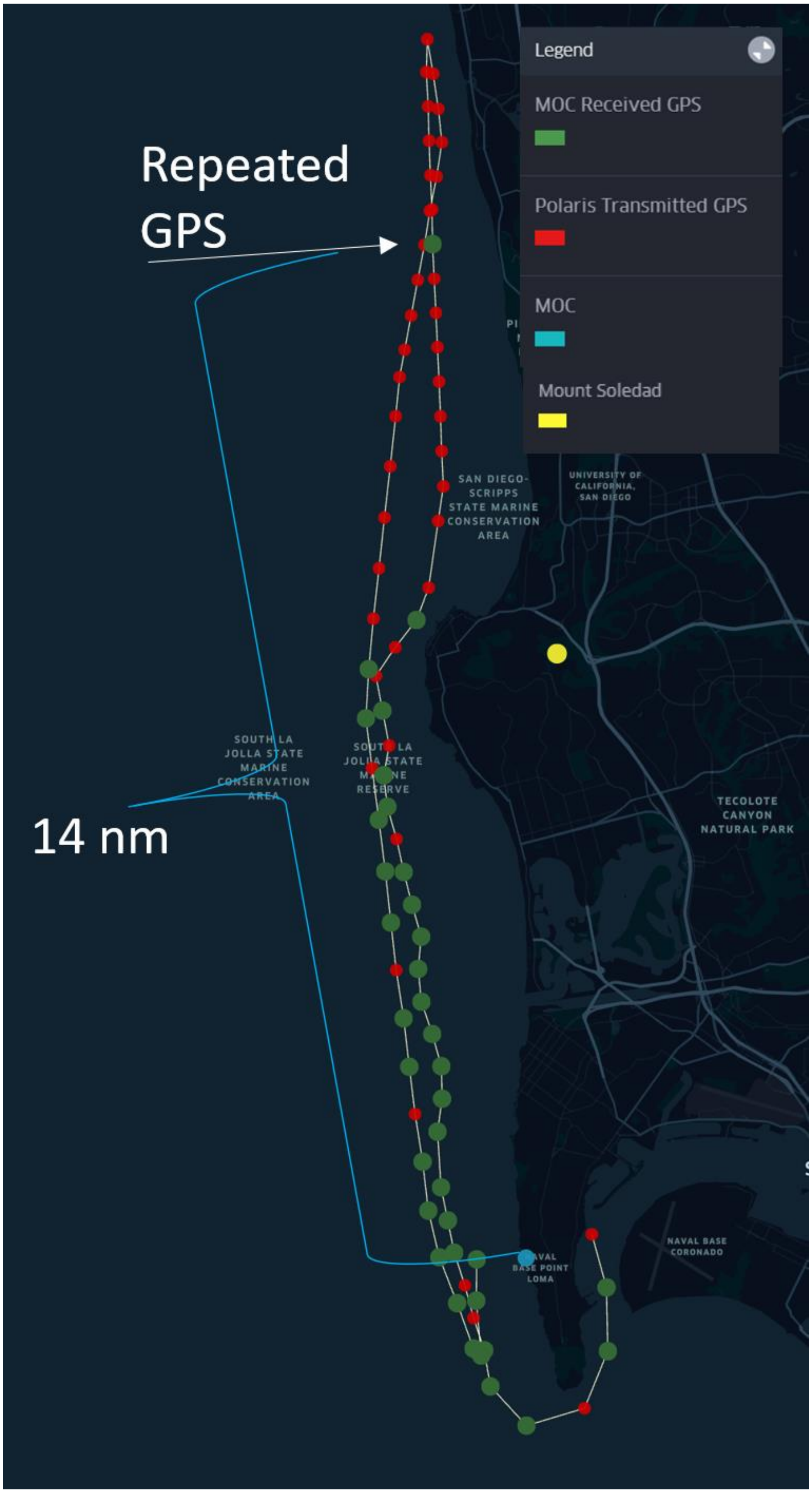

Figure 6. Day 1: Mount Soledad AtoN Repeating AIS Type 6 Msg.

Although Mount Soledad has an elevation of 250 m there was an elevation obstruction between Mount Soledad and the MOC, resulting in the inconsistent reception of the GPS using the AtoN repeater. Figure 7 shows the elevation from the MOC (site of the COA System) to Mount Soledad (site of AIS repeater). Based on Google's Earth Elevation plot there is a 73 m obstruction between the MOC shore site and the AIS repeater location on Mount Soledad.

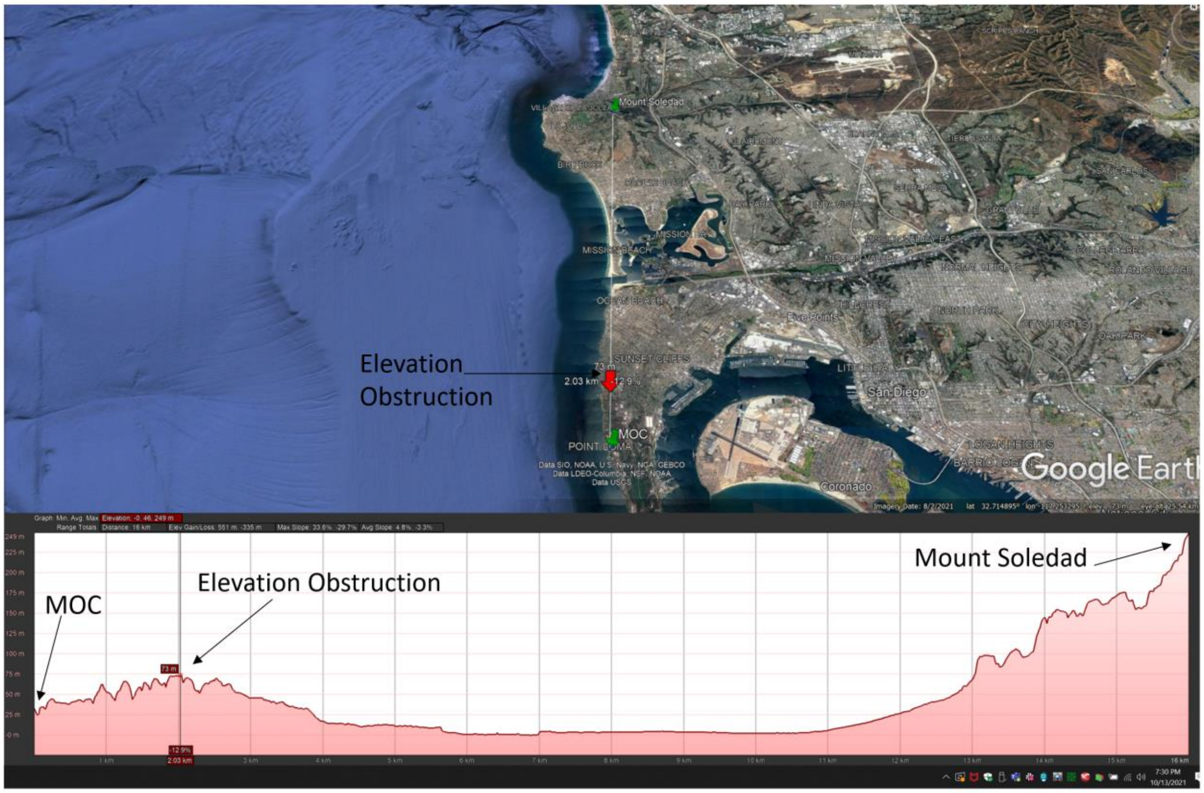

Figure 7. Elevation between the MOC and Mount Soledad.

1.2.2.2 Propagation Ducting Off SOCAL

The author contacted propagation experts Mr. Hank Owen (H.S. Owen LLC) and Mr. Lee Rogers (NIWC Code 55280) to help explain the lack of continuous RF coverage between the MOC and in the Polaris in Figure 6. Mr. Owen provided historical received power measurements of vessel's AIS transponders of off SOCAL to help understand propagation ducting in this area. Note that these measurements were collected near the MOC's location in Point Loma.

Figure 8 represents the received power from a Vessel with AIS MMSI number 441344000 and its corresponding AIS position data on August 10, 2021. In this figure, the green line connects terrestrial and satellite AIS data for this vessel shown in the SV interface. Worth nothing is that the received power is not continuous over the entire vessel's voyage from San Diego towards Long Beach.

COA uses the Mando 303 AtoN, which has a received power level of -107 dBm which is marked as a red line in Figure 8's power plot. Using the received power versus range plot, the AtoN's capability to receive at some specific ranges makes sense.

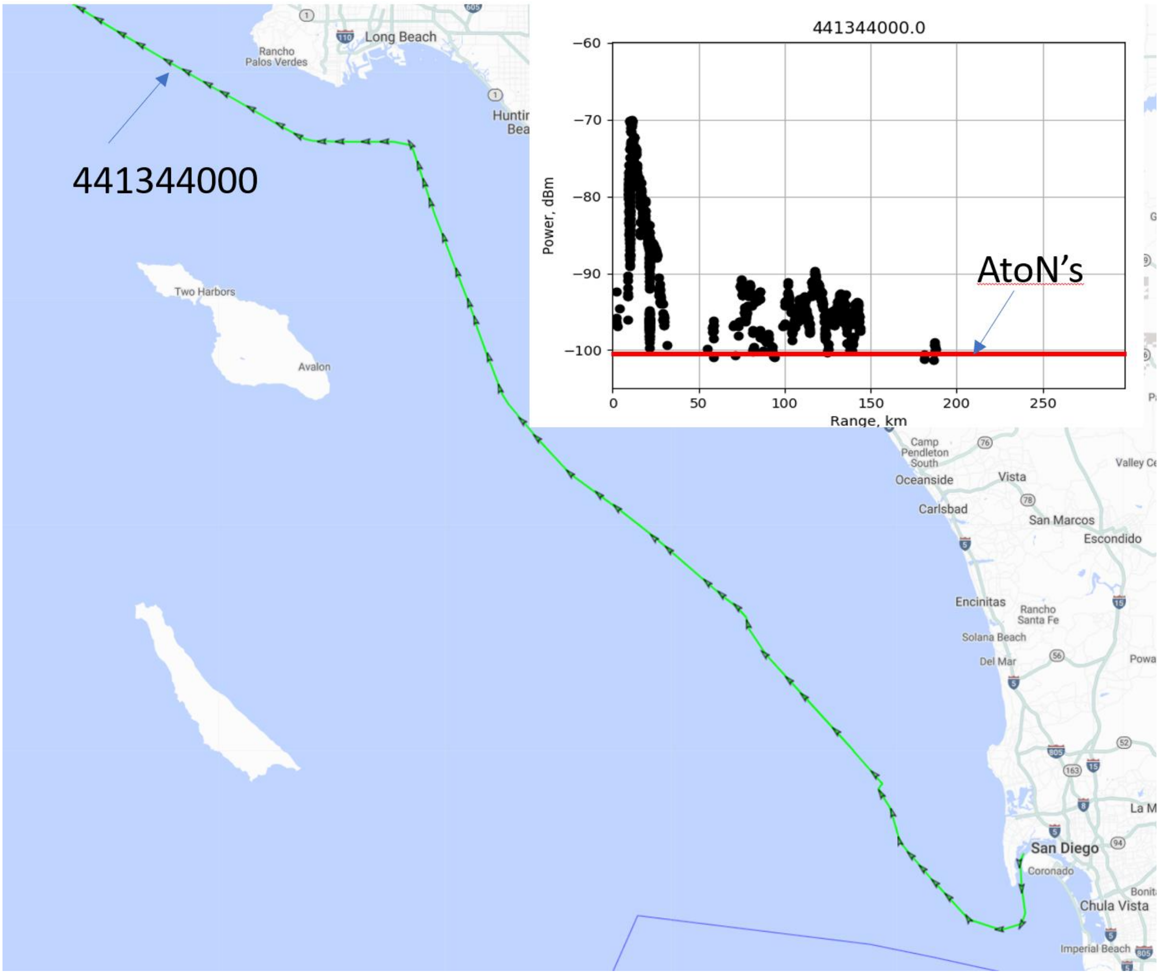

Figure 8. Received Power for Vessel's AIS Transponder and AIS Data August 10, 2021

Figure 9 shows the propagation ducting nulls (yellow lines) based on the received power plot. The location of power intensifications and nulls in the ducting environment is a function primarily of the water vapor profiles of the Marine Atmospheric Boundary Layer (MABL). The water vapor profiles are subject to random processes such as turbulence and wave motion on MABL.

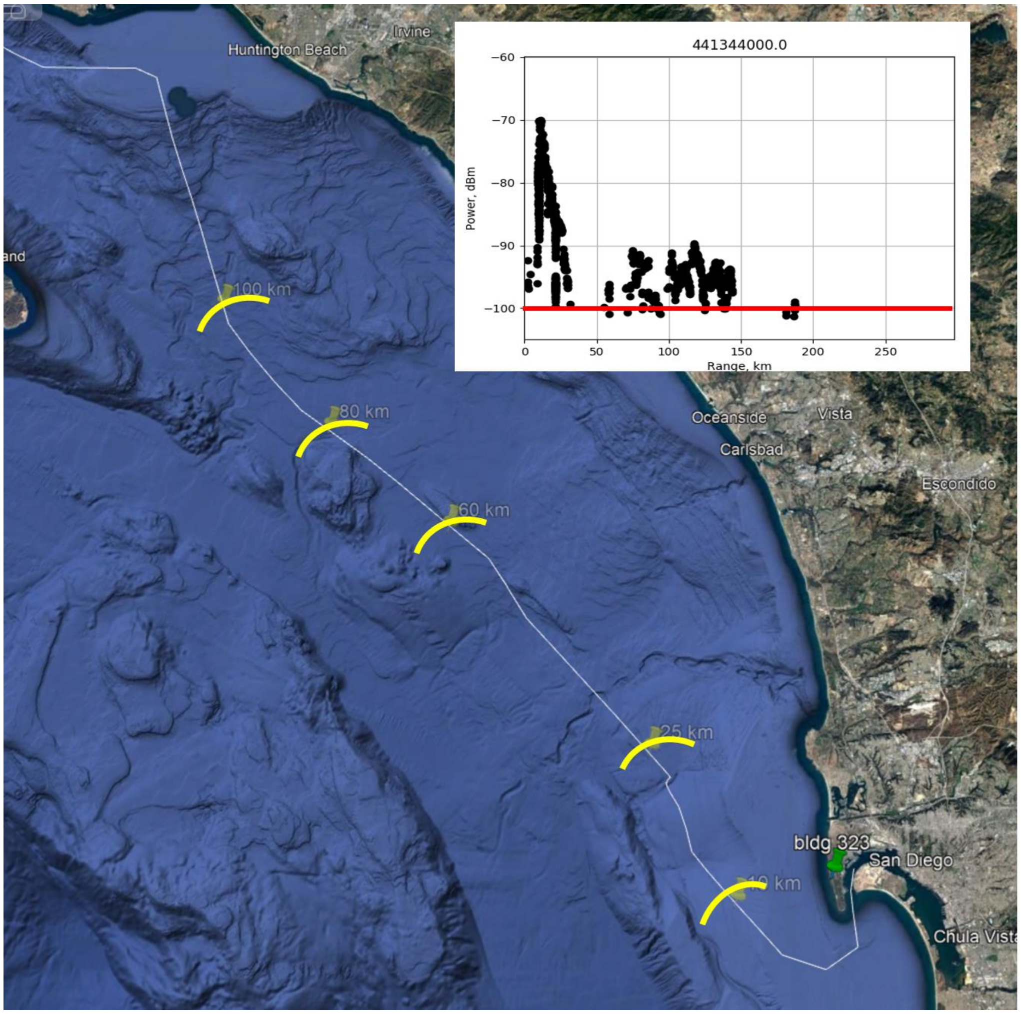

Figure 9. Received Power Not Continuously Received.

An illustrative example of the MABL dynamic nature in time is a plot from Variability of Coastal Atmospheric Refractivity (VOCAR) experiment that took place in the SoCal in 1993. Figure 10 from [Rogers, 1996[5]] shows the propagation factor ("F", power referenced to the calculated line-of-sight power "LOS") at 262 MHz on a low-altitude path from San Clement Island to Point Loma over a period of approximately 100 days.

5 Rogers, L., (1996), Effects of the Variability of Atmospheric Refractivity on Propagation Estimates, IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. 44, NO. 4, APRIL

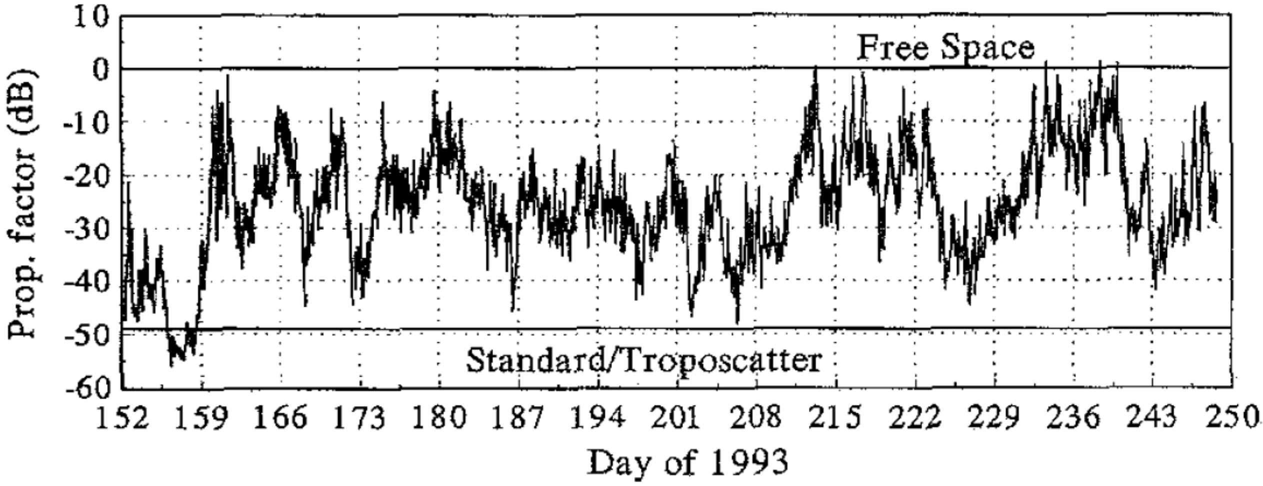

Figure 10. Propagation Factor Time Series 262.85 MHz.

The variability of effects is present in azimuth as well. Figure 10 is an example from the east coast (Wallops Island VA) showing the dynamic variations in power as a function of azimuth based upon a high-power (1 MW) radar [see Gerstoft, et al., 2003[6]].

1.2.2.3 Chat Messages Vessel and Shore (MOC)

The Polaris COA operator and the MOC were able to text and receive 74% of their messages during the entire transit of Polaris on Day 1. Figure 12 shows that over 66% of the messages transmitted between the Polaris and the MOC required only a single transmission. Retransmission occurs when the COA system does not receive an acknowledgment message within a user defined time period. Note that the number of retransmits was limited to five for day 1 testing and decreased to two for the remaining test days. The AtoN repeater does not repeat the acknowledgement message. As a result, messages may arrive out of sequence thus making it difficult to follow a specific vessel's message thread. To address this the problem the COA software would need to be modified to not retransmit when an acknowledgement message was not received.

[6] Gerstoft, et al., (2003), Inversion for refractivity parameters from radar sea clutter, RADIO SCIENCE, VOL. 38, NO. 3

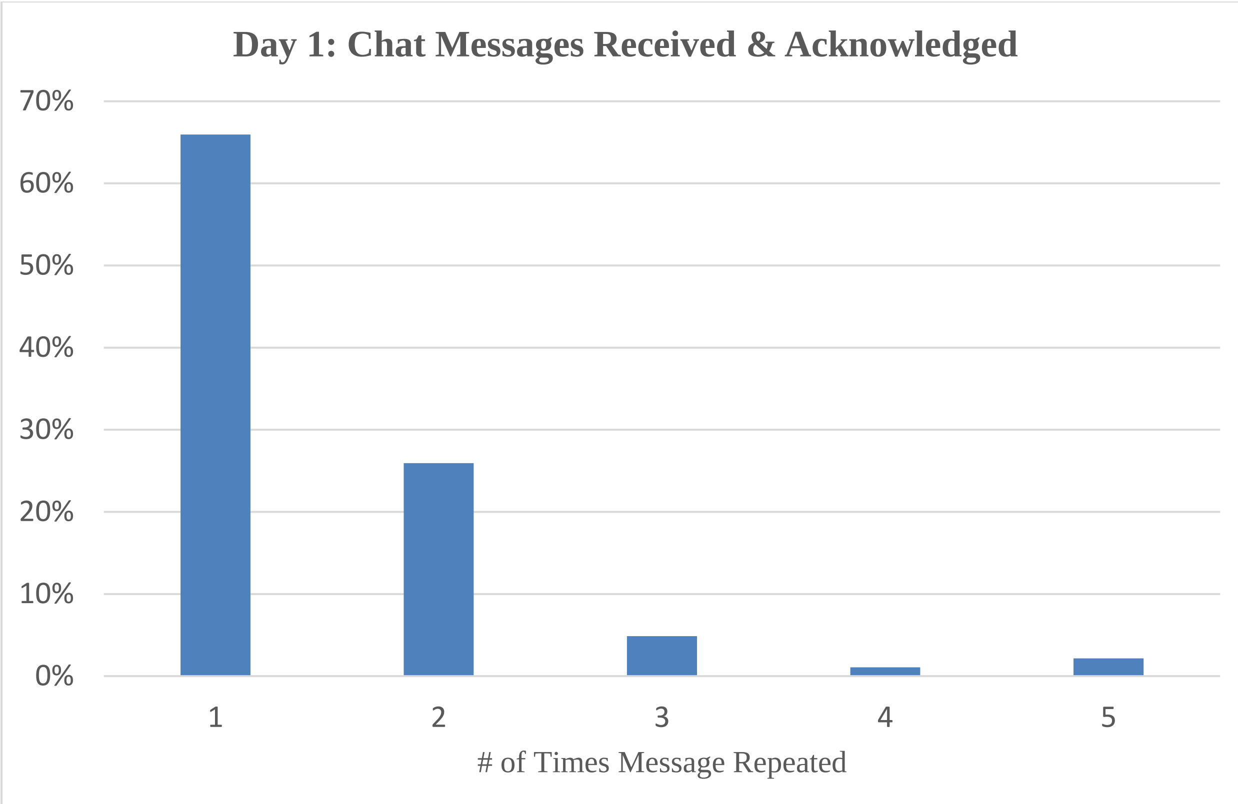

Figure 11. Day 1: Percent of AIS Type 6 Message Repeated.

1.2.2.4 Manual Reports

The Polaris COA operator sent nine Manual Reports (MR) and five successfully displayed in SeaVision, Figure 13. The limited number of MR pushed from Polaris was due to the COA not providing a good interface for easily entering the required information. As a result, there were multiple MRs with incorrect GPS locations. Note, that the MRs should all be off the SOCAL area. In addition, the MOC's WIFI was sporadic resulting in some MRs not being sent to the SV API.

Finally, the COA software should be modified to send the MR as a smaller AIS binary messages and then have the COA software recombine them prior to sending the MR into the SV's API. The Polaris COA operator noted that AIS messages that were sent in more than a single binary packet often failed to be received. Note, if all packets are not received then the message cannot be read by the corresponding AIS decoder software.

Figure 12. SeaVision Manual Reports Pushed from the Polaris.

1.3 DAY 2: SEPTEMBER 22, 2021

1.3.1 Purpose

- Have Polaris travel away from shore to prevent LOS elevation blockage.
- Test COA software
  - when within LOS of MOC
  - when vessel is not within LOS of MOC
- Do not use AIS repeater mounted on Mount Soledad for COA type 6 messages

1.3.2 Results

1.3.2.1 GPS Transmitted & Received AIS Type Messages

Figure 13. represents the GPS position data transmitted from the Polaris (red dots) and received at the MOC (green dots). The MOC's location (denoted by a light blue dot) was able to receive the GPS position data at 27 nm but not continuously due to propagation null described in section 1.2.2.2.

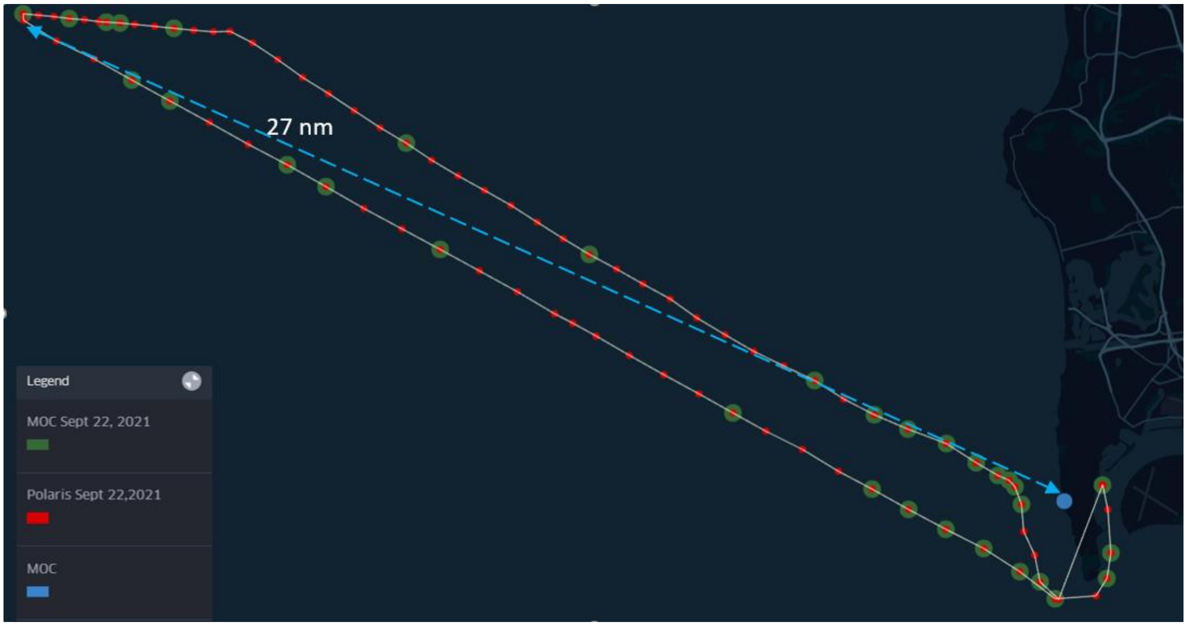

Figure 13. Day 2: GPS Sent from Polaris and Received by MOC.

1.3.2.2 Chat Messages Vessel and Shore (MOC)

The Polaris COA operator and MOC were able to text and receive 68% of their messages during the entire transit of Polaris on Day 2 which is slightly less that Day 1 of 74% messages received.

Figure 15 shows that over 72% of the messages transmitted between the Polaris and the MOC required only a single transmission. Retransmission occurs when the COA system does not receive an acknowledgment message within a user defined time period. Note, that the number of retransmits was reduced from five to two for day 2 testing.

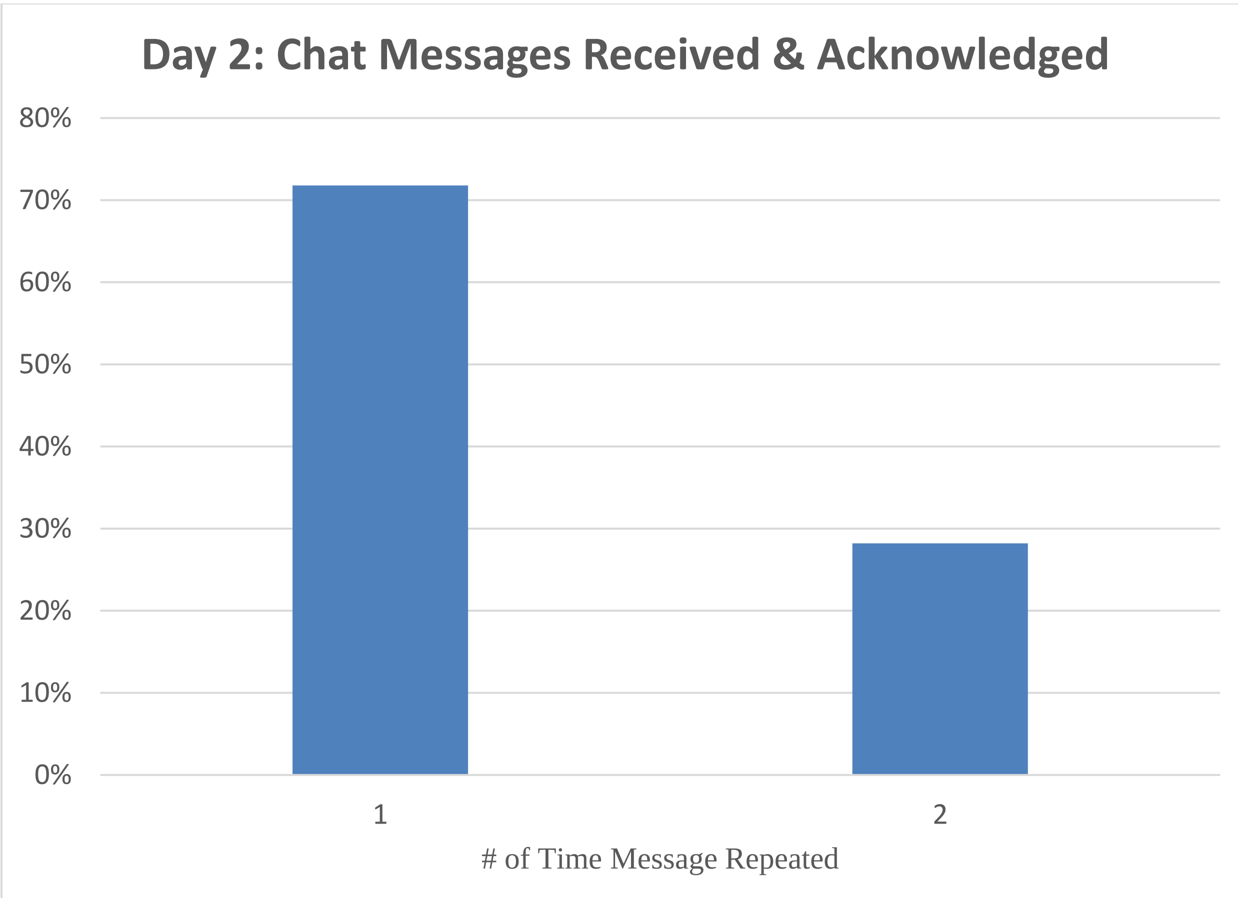

Figure 14. Day 2: Percent of AIS Type 6 Message Repeated.

1.3.2.3 Manual Reports

The Polaris COA operator sent twelve Manual Reports (MR) and two were successfully displayed in SeaVision, Figure 16. Note, if all packets are not received then the message cannot be read by the corresponding AIS decoder software.

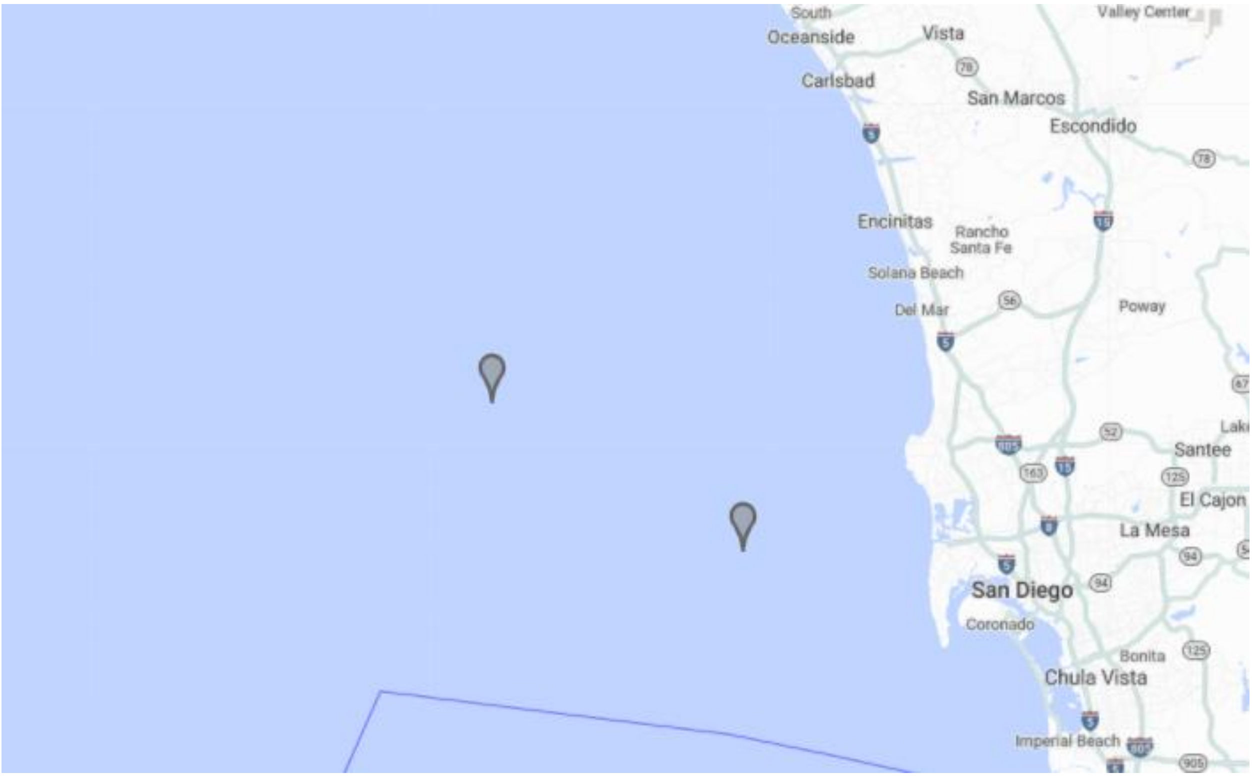

Figure 15. Day 2: Manual Reports in Sea Vision.

1.4 DAY 3: SEPTEMBER 23, 2021

1.4.1 Purpose

- Polaris traveled north towards Long Beach to support ROA testing
- Test COA software
    - when within LOS of MOC
    - when vessel is not within LOS of MOC
- Do not use AIS repeater mounted on Mount Soledad for COA type 6 messages

1.4.1.1 GPS Transmitted & Received AIS Type Messages

Figure 17 shows the Polaris GPS data transmitted (red dots) and received at the MOC (green dots). The MOC was able to receive the GPS data when the vessel was 13 nm away which was slightly higher than the estimated 11 nm calculated using Equation 1; however, as shown is section 1.2.2.2. the LOS can vary and be discontinuous.

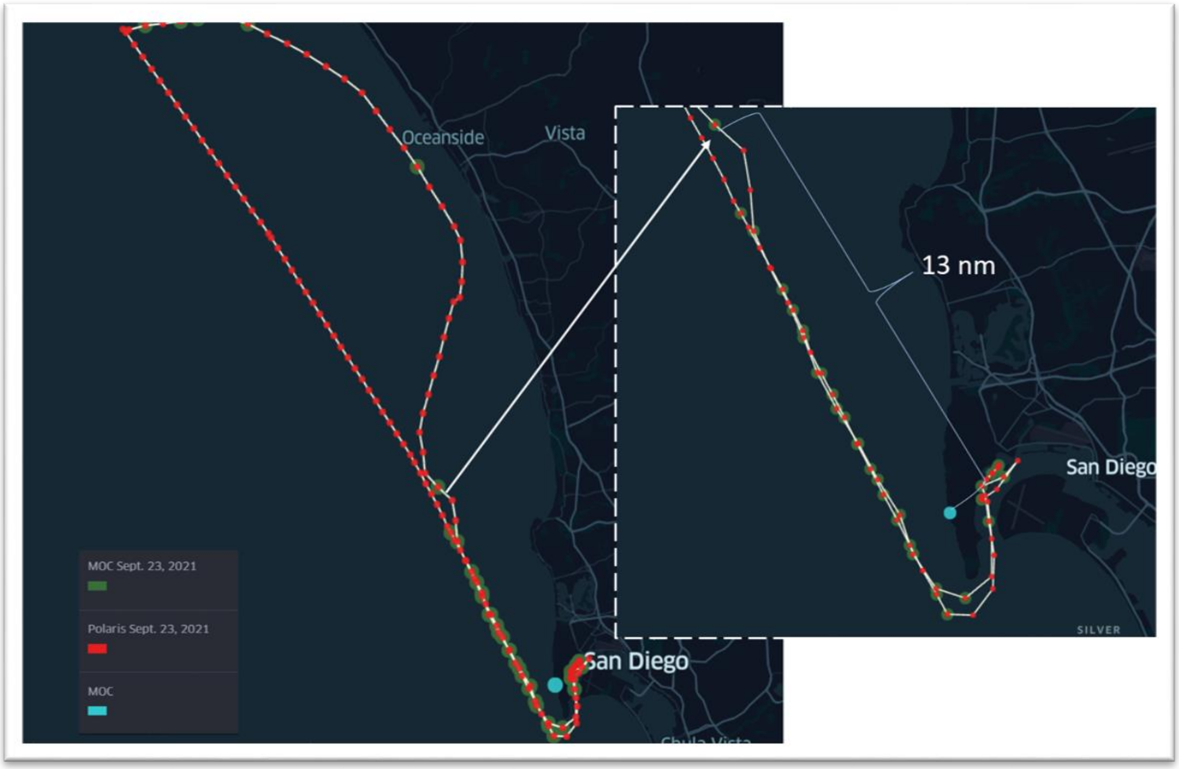

Figure 16. Day 3: GPS Sent from Polaris and Received by MOC.

Figure 18 shows that the MOC was able to receive a GPS position from the Polaris at 43 nm away. Again, the results of ducting.

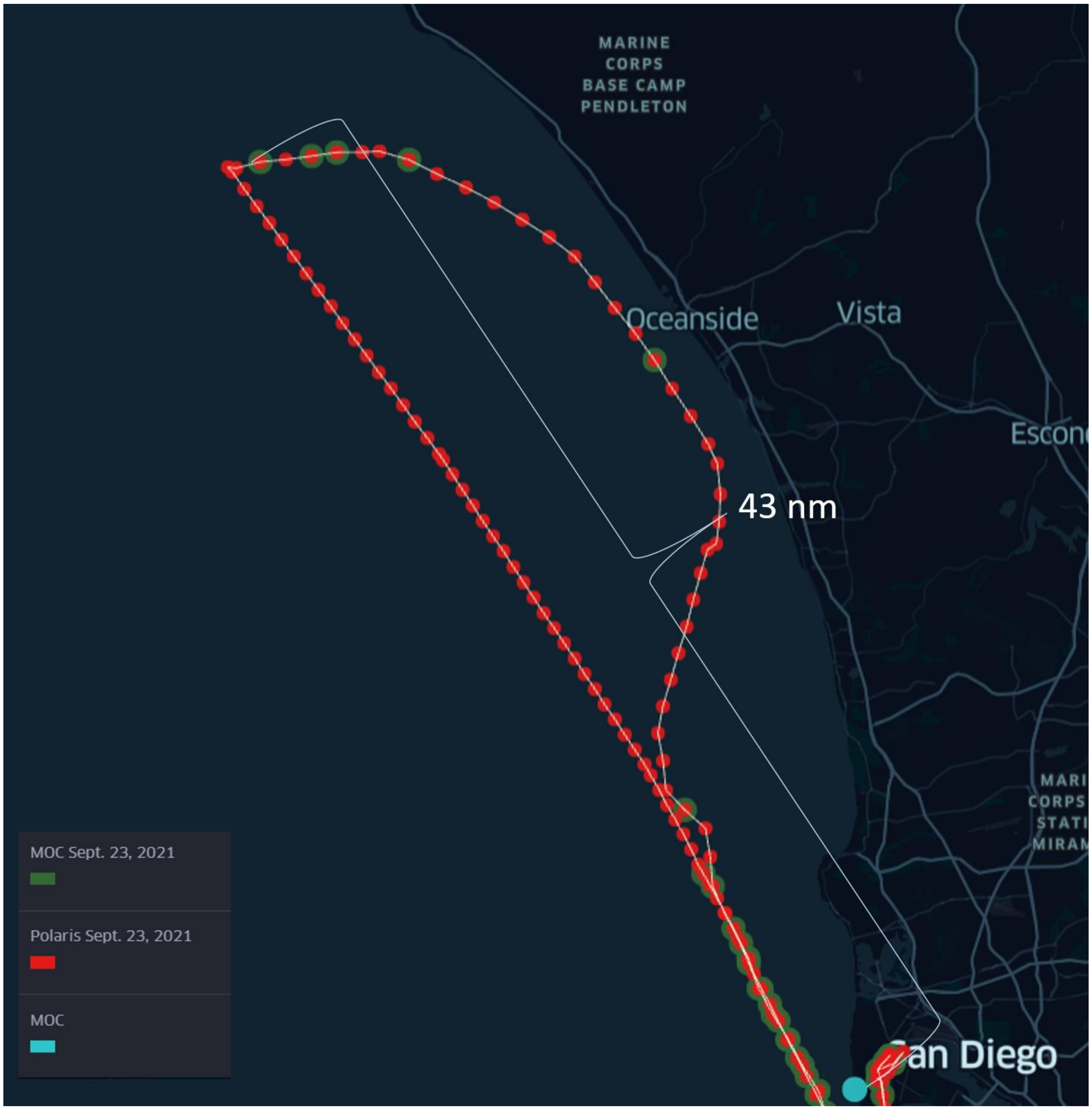

Figure 17. Day 3: Long Range GPS Sent from Polaris and Received by MOC.

1.4.1.2 Chat Messages Vessel and Shore (MOC)

The Polaris COA operator and MOC were able to text and receive 42% of their messages during the entire transit of Polaris on Day 3 which was less that Days 1 and 2.

Figure 19 shows that over 76% of the messages transmitted between the Polaris and the MOC required only a single transmission.

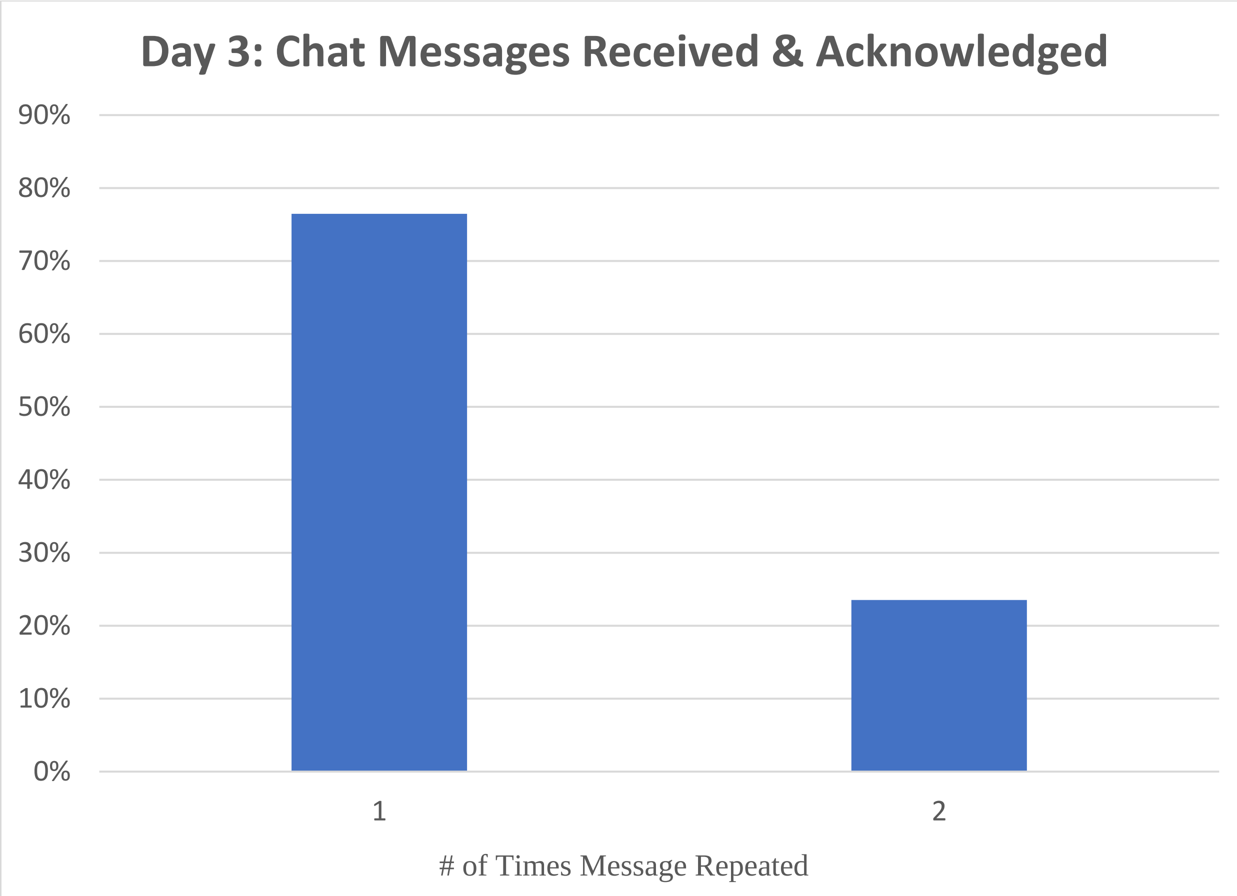

Figure 18. Day 3: Percent of AIS Type 6 Message Repeated.

1.4.1.3 Manual Reports

Polaris attempted to send eight MRs with only one MR displaying in SV, Figure 20. The lack of MRs making it into SV is a combination of the LOS and propagation ducting conditions. In addition, a MR requires three AIS packet sequences which makes it more difficult since all three messages must be received and decoded prior to sending the data into SV.

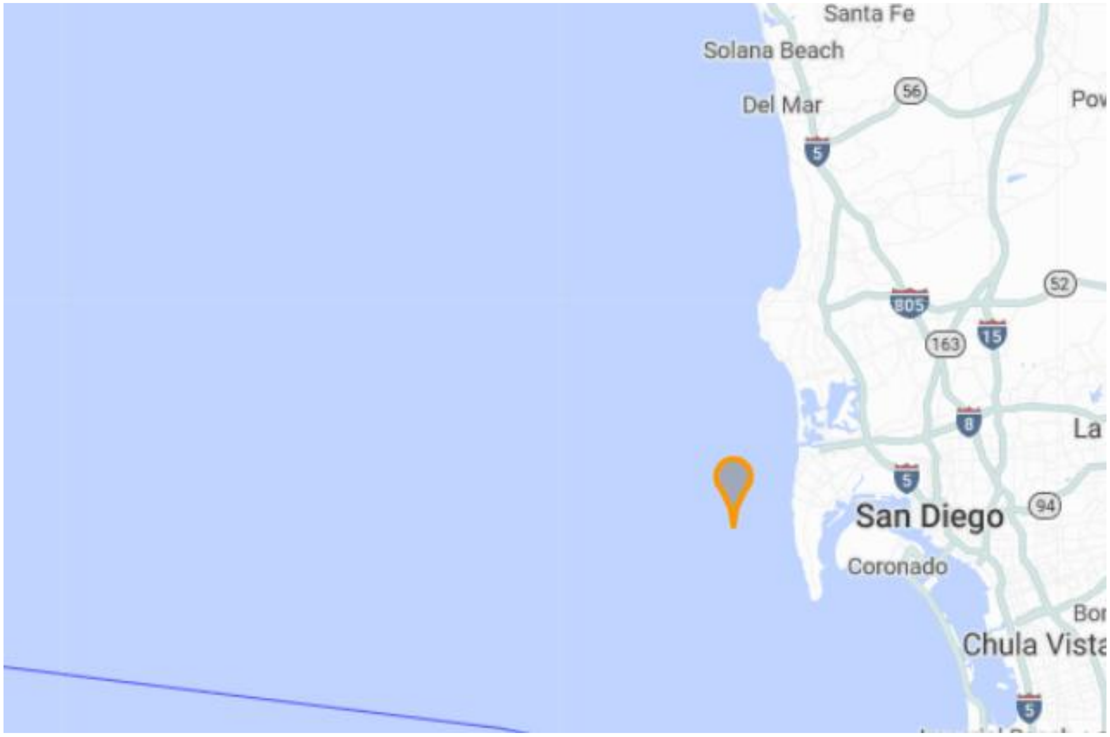

Figure 19. Day 3: Manual Reports in SeaVision.

1.5 VESSEL TWO LOGS

Figure 21 shows Vessel Two's GPS transmitted using AIS message type 6 over the vessel's 10 days of sailing. Note that the vessel completed two round trips during this time period.

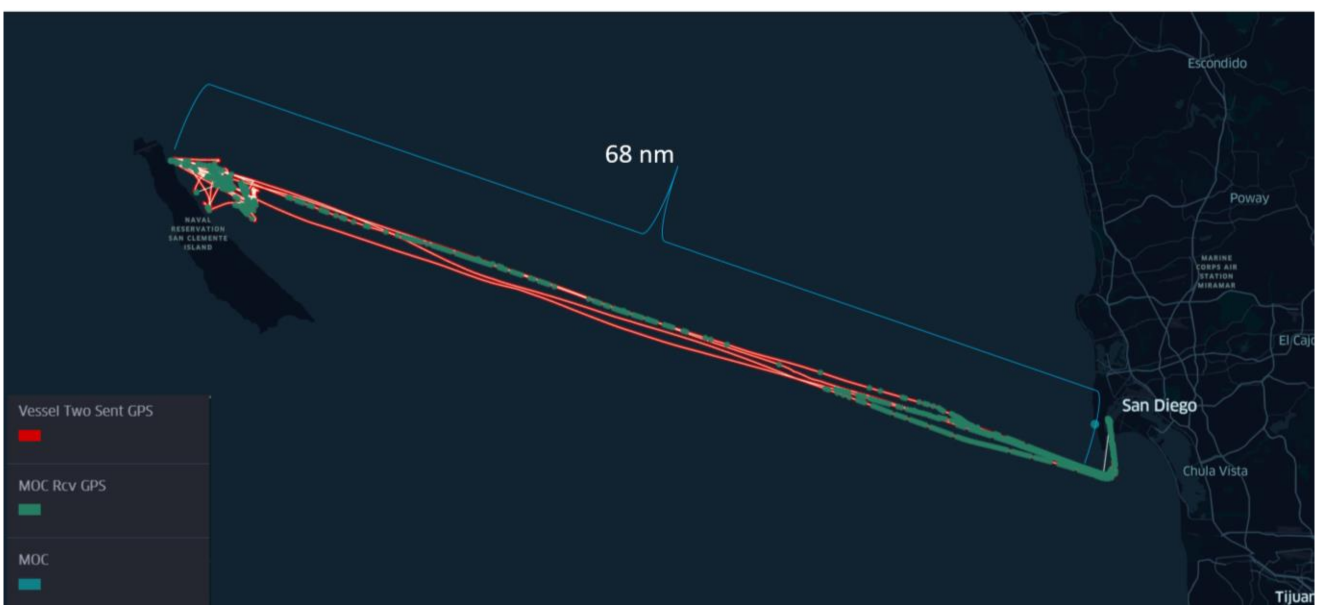

Figure 20. Vessel Two GPS Chat Messages Over Ten Days.

2. CONCLUSIONS

The COA capabilities were tested over three days of testing. Based on test results the following modifications are recommended for COA:

- Reduce the GPS and MR messages packets sizes so this data can be sent as one AIS message instead of three for each of these messages. Reducing the number of AIS packets will increase the probability that these messages will be received correctly when transmitted.
- Provide a better user interface for MR. Automatically populate position fields, time, date and allow user to have a pull-down option to select a reason for the MR or allow user to enter a reason. The current method for MR is very cumbersome, which can lead to operator error.

2.1 RECOMMENDATIONS

Overall, users aboard the vessels and at the MOC were happy with the COA interface design and the ease of use. A merchant marine aboard Vessel Two commented on how this capability was needed to easily communicate if vessels near them needed assistance when outside cell phone ranges. COA is a niche capability that would greatly benefit areas where VHF radio operators have difficulty understanding each other due to language. They could follow up a radio conversation with a COA text to verify information that may be difficult to relay over voice.

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

Chat Over AIS (COA) provides a user-friendly "Rocket Chat" interface which allows users to communicate by text using Automatic Identification System (AIS) message type 6. AIS message type 6 was designed to allow users to send and receive direct messages using their vessel's Maritime Mobile Service Identity (MMSI) number. In addition to providing an improved user interface, COA provides re-transmission of a text message if the vessel is not within Radio Frequency (RF) Line of Sight (LOS) range. For example, if a sender's vessel is not within LOS of the receiving vessel, then the sender's messages are periodically resent until the receiving vessel is within LOS.
COA also provides the capability to send GPS messages via text which allows Navy vessels to report their positions to their Maritime Organization Center (MOC) if the vessel does not want to transmit their position to surrounding vessels. COA utilizes an Aide to Navigation (AtoN) which is designed for data transmission and not vessel collision avoidance. Standard Class A or Class B AIS Transponders are designed for collision avoidance and they will automatically report a vessel's position.
In addition, vessels will be able to automatically send a Manual Report Event into the SeaVision (SV) Website. Adding the event automatically to SV allows MOC operators to see the Manual Report and then act on this information.

15. SUBJECT TERMS

AIS; VHF; Chat

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