Naval Information Warfare Center PACIFIC

TECHNICAL REPORT 3214
OCTOBER 2020

Chat-Over-AIS System Test Report OBANGAME Express 2019

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Administrative Notes:
This report was approved through the Release of Scientific and Technical Information (RSTI) process in August 2020 and formally published in the Defense Technical Information Center (DTIC) in October 2020.

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ADMINISTRATIVE INFORMATION

The work described in this report was performed by the Maritime Intel Systems Branch (Code 56260) of the ISR Division (Code 56200), Naval Information Warfare Center Pacific (NIWC Pacific), San Diego, CA. Funding provided by the Commander, U.S Naval Forces Europe-Africa / U.S. 6th Fleet.

Released by
Doug Herbers, Division Head
Maritime Intel Systems Branch

Under authority of
Rudy Nichols, Department Head
ISR Division

Edited by:
Robert J. Price

EXECUTIVE SUMMARY

This report focuses on exploring ways to utilize the Automatic Identification System (AIS) in innovative ways to deliver non-AIS data, such as coastal RADAR, using AIS channels. The AIS is an automatic tracking system used on ships and by Vessel Traffic Services (VTS). AIS systems send vessel position reports using dedicated Very High Frequency (VHF) frequencies. While AIS is normally used for collision avoidance, there are other potential uses for AIS that were investigated in our study. Those potential uses are detailed in this report.

Use of the AIS systems as an information conduit channel takes advantage of AIS system capabilities to exchange messages with a custom payload. The payload of the CHAT-over-AIS messages contains chat text messages sent between AIS transponders as a means to relay text data instead of relying on VHF radio for communication between either ship-to-ship or ship-to-shore.

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ACRONYMS

AIS – Automatic Identification System

AtoN – Aids to Navigation

COA – Chat-Over-AIS

ECR – Exercise Control Room

MMSI – Maritime Mobile Service Identity

MOC – Maritime Operations Center

SD –Secure Digital

VHF – Very High Frequency

VTS – Vessel Traffic Services

VWSR – Vertical Wave Standing Ratio

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1. INTRODUCTION

Senegal is a country located in Western Africa bordering The Gambia and Mauritania. Senegal has been participating in OBANGAME Express exercises for several years. It was chosen as a site to test because it has a well equipped infrastructure to test Chat Over AIS (COA). It was the location for testing COA during Operation Junction Rain Testing in 2018 (OJR18).

During OE19, the COA systems was installed at five locations as indicated in Figure 1. The COA system was installed on vessels and shore sites to verify the following communication paths:

- Ship-to-Ship
- Ship-to-Shore
- and Shore-to-Shore.

To test the Ship-to-Ship communications, COA was installed on two vessels, the Senegalese Navy vessel Kedougou (Figure 2), and on the Gabonese Navy vessel Musamaliya (Figure 3). Installation on board the Gabonese vessel was the most challenging since there was limited space on the vessel mast for mounting the VHF.

To verify both Ship-to-Shore and Shore-to-Shore communications, the system was also installed at two Senegalese shore sites: the Dakar Navy base RADAR Tower and St Louis Navy Base RADAR Tower. To provide Dakar OE19 participants the capability to chat with vessels, the COA was also installed at the Dakar Navy Base Exercise Control Room (ECR), which was located approximately 0.2 nm from the Dakar RADAR Tower location.

Figure 1. Chat-over-AIS system locations for OE19.

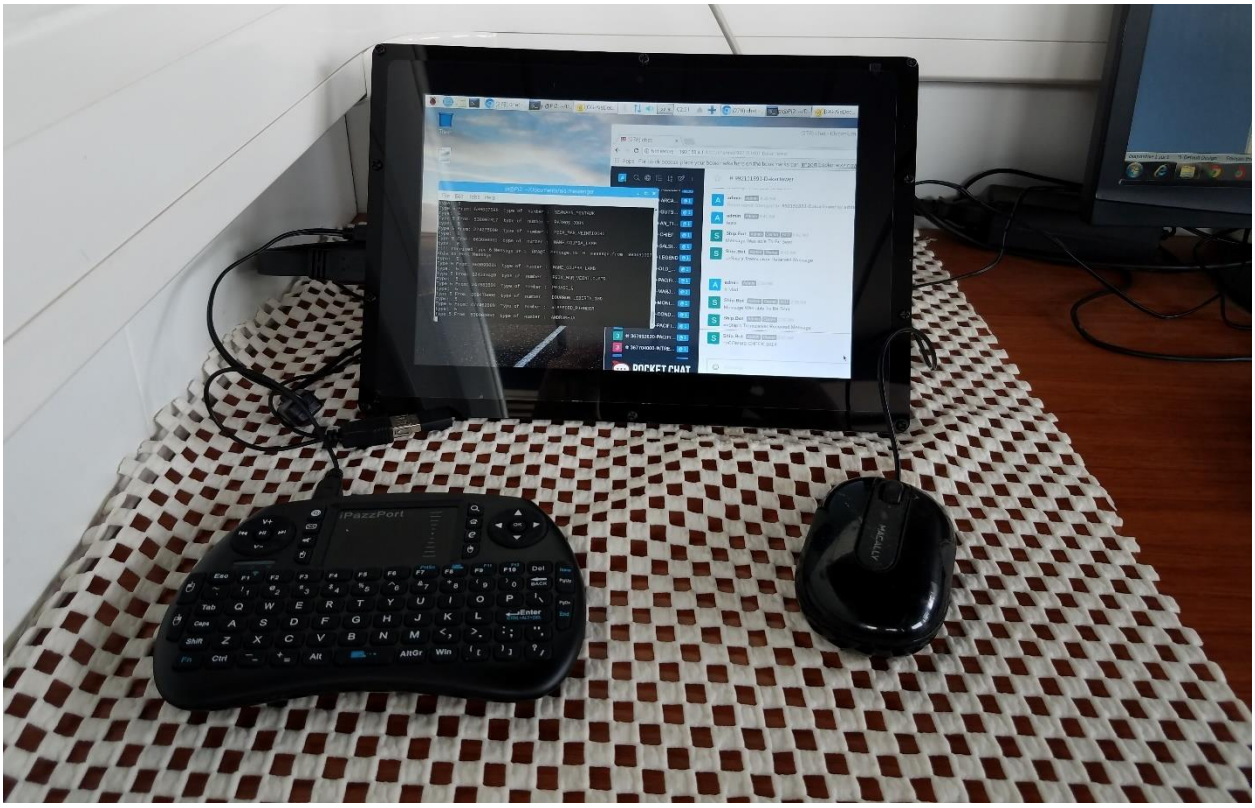

Figure 2. Chat-over-AIS installed on SEN Kedougou vessel.

Figure 3. Chat-over-AIS installed on GAB Musamaliya vessel.

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2. SYSTEM DESCRIPTION AND FUNCTION

The COA system user interface allows users to chat using Rocket Chat (an Open Source Chat Application) with vessels that have Class A AIS transponders. In order for the vessel to utilize the Chat-Over-AIS text messages, the vessel must be within VHF reception range. Class A AIS transponders have a defined addressed message Type 6, which provides vessels the capability to send/receive text messages; however, the user interface is slow and cumbersome. There is also a Type 7 acknowledgement message generated at the received AIS unit when the Type 6 message is successfully received.

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3. PLANNED OBJECTIVES

This is the second year that COA system has participated during an OBANGAME Express exercise; therefore, the objectives of this study were to address findings from OBANGAME Express 2018 (OE18) and test modifications and improvements made to the system.

3.1 RESULTS OF OBANGAME EXPRESS 2018

During OE18, the COA system was installed on a Beninese Naval vessel, OUEME P110, and at two shore sites. The COA system-maintained Ship-to-Shore communications with OUME when the vessel was within ~13 nm but communications failed as the vessel transited further from shore. The RADAR-Over-AIS system was also installed on the OUEME and this system was able to maintain communications up to 26 nm. Both Chat-Over-AIS and RADAR-Over-AIS utilize AIS transponders but each system was using different AIS hardware. After the exercise, it was determined that the COA AIS transponder was overheating which was causing the system to fail. In addition, the AIS unit diagnostics showed a Voltage Standing Wave Ratio (VSWR) of 1.25 which indicated power is reflected back instead of delivered to the antenna.

3.2 SUMMARY OF RECOMMENDATIONS FOR COA SYSTEM FROM OE18

3.2.1 Communications:

1. Determine why the AIS communications range was significantly less that RADAR-Over-AIS unit and replace AIS hardware as required.
2. Verify cables with a network analyzer prior to install and check that VSWR is ~one.
3. Replace the AIS antenna with a higher gain antenna to improve communications.

3.2.2 Other Recommendations:

1. Investigate using a smaller and less expensive form factor computer than a laptop such as a raspberry pi computer.
2. Provide users with a WIFI enabled tablet with chat capabilities so that users did not have to sit at a fixed computer or use their personal cell phones to chat.

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4. SOFTWARE MODIFICATIONS

The COA software was modified to run on a Raspberry Pi and to utilize the open source software Rocket Chat. Modifications of the COA software were difficult since the Raspberry Pi's Linux build was not the same operating system that was used on the laptops during OE18. Additionally, documentation to install and maintain the Rocket Chat Software on the Pi was limited.

The COA software was modified to support both the L3 AIS and the Mando 303 AIS transponder hardware. Although the AIS output messages are standard National Marine Electronics Association (NMEA), the internal messages sent to the hardware devices via serial cable vary by hardware vendor. The lack of documentation required trial and error in order to verify that the output NMEA messages were correct. For example, the Message type 6 has a field to keep re-transmitting but instructions on how to request this option was not documented and the vendor was not able to provide information on how to enable this field in the NMEA output message. Consequently, we were left to explore possible solutions through trial and error until we found a setting that would work.

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5. HARDWARE MODIFICATIONS

We installed the COA application on Raspberry Pi devices for use on both vessels and at three land sites. The Raspberry Pi has a reduced Linux Operating System and boots off a Secure Digital (SD) Card. It provides a WIFI hub so users can use either their own cell phone or tablets procured to allow users a larger screen for chatting. As a back up to the Raspberry Pi computer, we also installed the new COA software on laptops and connected them to WIFI routers enabling users to access chat using their cell phones, vice relying on a laptop screen.

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6. TEST PURPOSE

The purpose of this test was to increase Maritime Domain Communication for Senegalese and Gabonese territorial waters by allowing Port Officers and Patrol boats to chat with other vessels instead of relying solely on voice radio communication. Port Officers and Vessel Masters communicate over the radio in English but often this communication is not clear either due to noise on the VHF frequency or users speaking in a non-native language.

The secondary purpose was to test the COA System communication range using the same AIS transponder hardware as the RADAR-Over-AIS system. In addition, the COA system was ported onto a Raspberry Pi computer to test using a less expensive form factor. Finally, the AIS antenna was upgraded to a Morad VHF 162 AIS antenna, which increased the COA system transponder gain by 6 dB compared to OE18.

6.1 TEST DATES AND LOCATION

The Chat-Over-AIS (COA) system was installed and tested in two countries: Senegal and The Gambia from March 9 – 21, 2019 during the OBGAME Exercise 2019 (OE19).

6.2 INSTALLATION AND TEST TEAM

The COA system team included Lynne Tablewski, Vladimir Matveyev, and Doug Herbers.

6.3 SYSTEM COMPONENTS

The COA system components consisted of: Class A AIS Transponder, Mando 303 Aid to Navigation (AtoN), VHF Antenna Morad VHF 162, GPS Antenna, power supply cable for 12 VDC, laptop or Raspberry Pi B, RCA 7” Voyager Android 16G tablet and a wireless router.

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7. RECOMMENDED IMPROVEMENTS

7.1 SOFTWARE ASSESSMENTS

1. Test COA by creating invalid AIS messages and injecting them manually into COA. COA was tested in San Diego prior to OE 2019 but the system did not receive invalid AIS messages during testing.
2. Turn off creating new AIS chat rooms since this was confusing for users. Fix software to archive chat rooms if the requirement to add chat rooms is still needed.
3. Modify the COA software to continue retransmitting a user's type 6 message until a Type 7 acknowledgement is received from the system.
4. Alert users when their chat message has been received from the other vessel. This will occur when the other ship is within VHF range that may not occur while the user is looking at COA screen.
5. Configure the COA to send back GPS positions so the MOC knows their own Naval Ship's position but don't use the standard type 5 message. The Mando 303 is an Aid to Navigation (AtoN) that has the capability to send type 21 message with its GPS coordinates. This was turned off during OE 2019 to reduce VHF message traffic.

7.2 HARDWARE ASSESSMENTS

1. The Mando 303 AIS transponder performed without problems and provided the capability for vessels to not transmit their own position, which is a common practice for naval vessels.
2. Replace the Raspberry Pi 3 with low cost computer
3. RCA Voyager Tablet's memory, 1 GB DDR_SDRAM, was not sufficient to browse the Rocket Chat COA website resulting in very slow response when using the tablet.

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8. CONCLUSIONS

The VHF connectivity was improved from OE18 by switching to a newer AIS transponder and higher gain antenna. Switching to the Raspberry Pi caused the system to fail; however, it was worth attempting since the Pi's cost is approximately $35. Chat-Over-AIS has the potential to become a low-cost, low-maintenance, user-friendly and simple to operate system that can be used to supplement and simplify existing VHF communications. Chat-Over-AIS was a new concept for most users but they did see the value of the easy-to-use Rocket Chat Software over having to turn the knob on a Class A AIS transponder to send a message. The advantages of the system over traditional VHF radio are as follows:

- Chat communications are not disrupted by interference or noise.
- Can improve the language barrier since users can use Google Translate on the text.
- Provides a written communications trail.

Proposed COA improvement:

- Send chat messages until receiving AIS unit sends and acknowledge message.
    - Vessels travel in/out of VHF communication that deters users from actively chatting. Therefore, continuously sending a message is recommended.
- Transmit a vessel position's back to MOC and display its position in the vessel's chat room as a specific rate
    - Normally, naval vessels do not transmit their position; however, based on input from the Senegalese Navy MOC officers they would like to know the positions of their naval vessels.
    - AtoNs have message type 21 that is for AIS to Navigation Report and not a standard vessels GPS position.
- Relay position information back to MOC of specific vessels of interest.
    - The Senegalese Navy MOC Officers gave an example of a local ferry that they would like to track using COA as a relay of this vessel's position.
- Improve the Chat User Interface.
    - RocketChat is an open source web server based software that is not intuitive for infrequent chatting or loss of communications.

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APPENDIX A
NIWC POINTS OF CONTACT

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APPENDIX B
SUMMARY OF DAILY EVENTS

Appendix B details Daily events that occurred during our tests conducted.

B.1 SHIP-TO-SHIP CHAT

SEN Kedougou and GEN Musamaliya:

March 18, 2019: SEN Kedougou chatted with GEN Musamaliya using COA at range of 13nm, (Figure B1 and B2) There was limited chat messages between the two ships since the GEN Musamaliya was not manned; if the COA software crashed, the system was not restarted. In addition, the GEN Musamaliya remained near The Gambia border and was not always in VHF range of the SEN Kedougou.

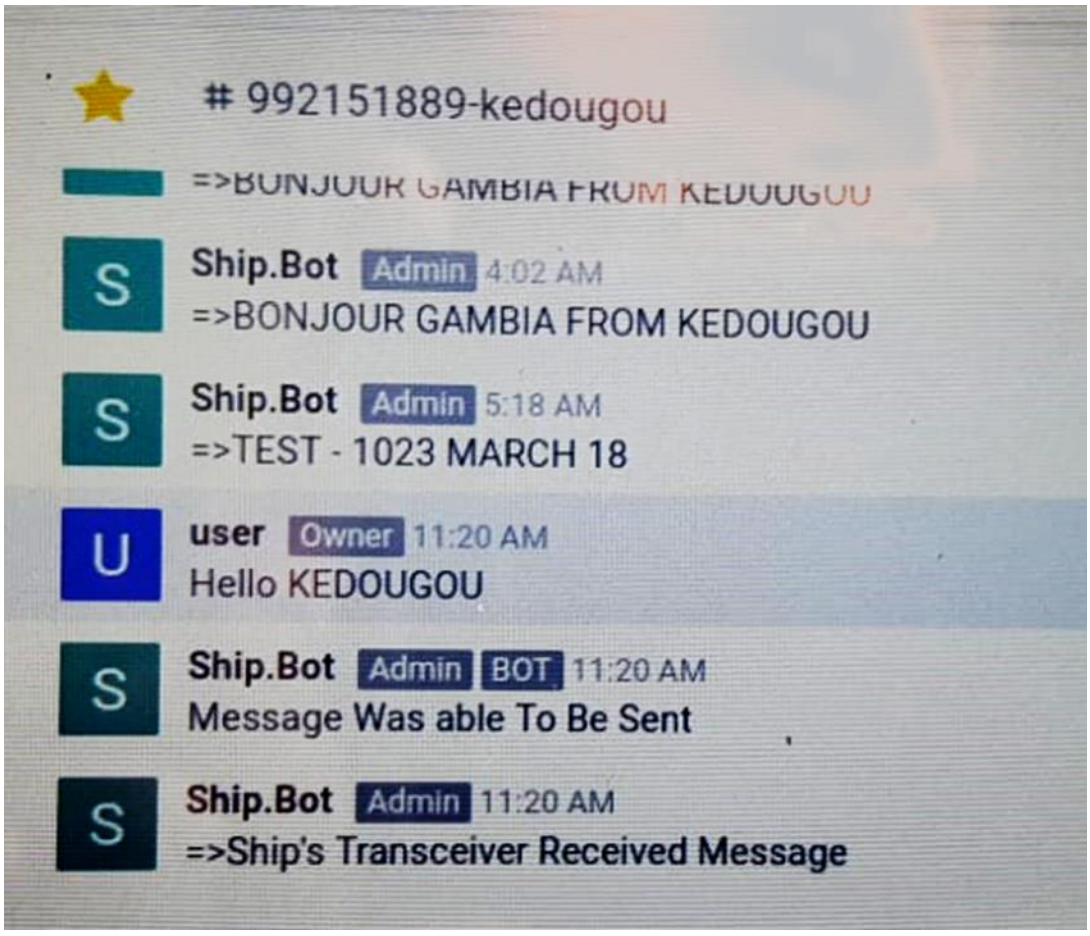
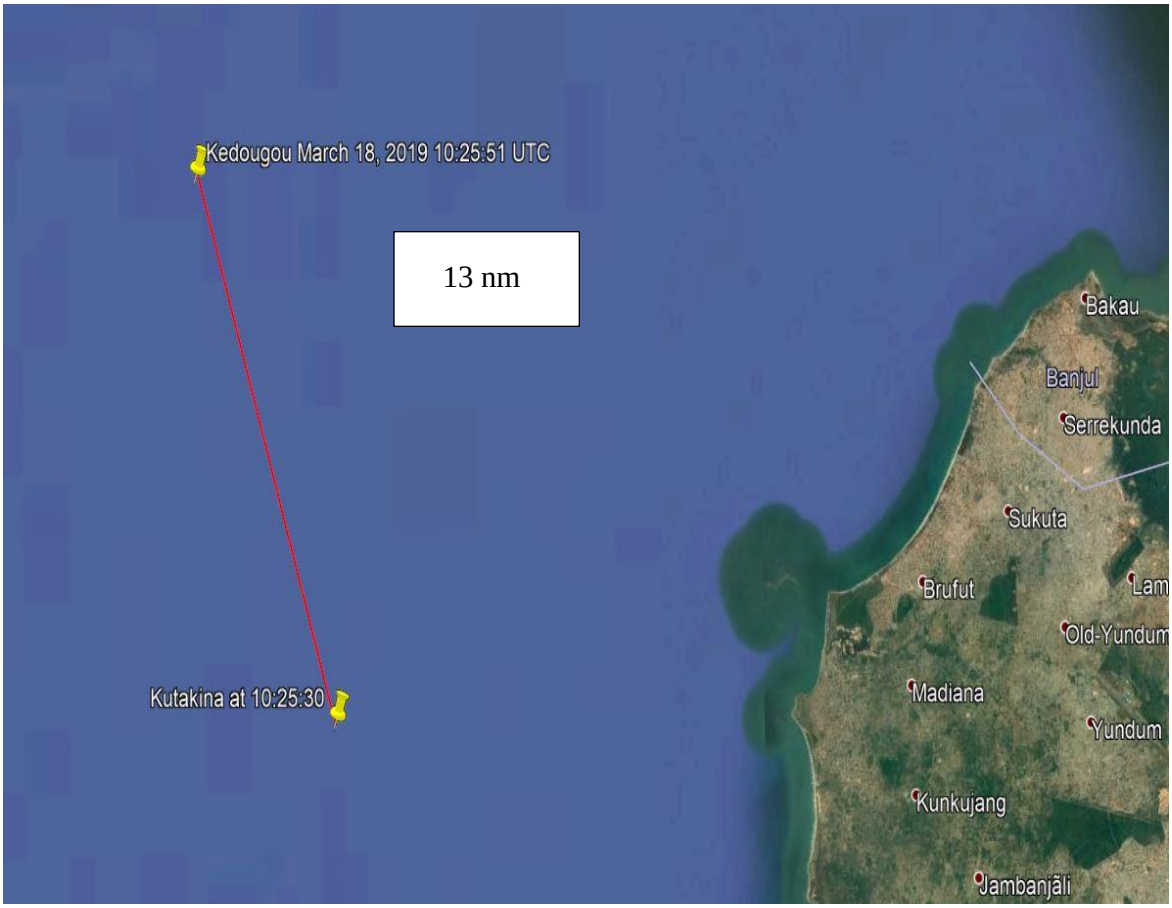


Figure B-1. SEN Kedougou and GEN Musamaliya chat log March 18, 2019.



- Photo supplied by Google Earth

Figure B-2. SEN Kedougou and GEN Musamaliya Ships 13 nm separation while chatting.

B.2.1 SHIP-TO-SHORE CHAT EVENTS

B.2.1.1 SEN Kedougou and Dakar RADAR Tower

March 11, 2019: unknown range since SEN Kedougou did not transmit a GPS position[1]

March 14, 2019: unknown range since SEN Kedougou did not transmit a GPS position

March 18, 2019: Range of 59 nm

[1] Mando 303 AIS is an Aid to Navigation (AtoN) which has the option to not transmit its GPS position. The ship did not have their installed AIS transmitting.

B.2.1.2 GEN Musamaliya and Dakar RADAR Tower

March 18, 2019: unknown range since GEN Musamaliya did not transmit a GPS position

March 19, 2019: unknown range since GEN Musamaliya did not transmit a GPS position

B.3.1 SHORE-TO-SHORE CHAT

March 12, 2019: Dakar RADAR Tower and Dakar Exercise Control Room (ECR), range of 0.2 nm

March 18, 2019: Dakar RADAR Tower and St Louis RADAR Tower, range of 95 nm

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APPENDIX C
LOG OF COA EXPERIMENT ACTIONS/ISSUES

C.1 MARCH 9, 2019: INSTALLATION OF COA ON BOARD KEDOUGOU AND AT DAKAR RADAR TOWER

- Install COA on SEN Kedougou
    - Senegalese Navy Technician ran DC power for AIS transponder and VHF/UHF cables for COA on board the Kedougou.
    - Setup up Raspberry Pi on ship's bridge. Tested and verified that an extended serial cable from the AIS transponder to the Pi did not result in data loss.
- Install COA at Dakar RADAR Tower
    - Tested out using a VHF antenna splitter for both COA and Radar-Over-AIS so both systems could utilize the same VHF antenna mounted to a 15 m tower located at Dakar RADAR Tower. Verified that the VHF splitter did not result in any problem with transmitting and receiving over COA.

C.2 MARCH 10, 2018 SOFTWARE ISSUES

- COA crashed when parsing invalid AIS messages
    - Modified COA software to gracefully not parse invalid AIS messages instead of crashing the COA software.
- Archive not working on chat rooms
    - Manually deleted vessel chat channels since this slowed down the Pi if there were outdated vessel channels.
    - Attempted to archive and unarchive vessel channels but software required more testing since the unarchived channel had only read permission. Decided to forego archiving chat channels with a plan to make this change once OE19 was over.

C.3 MARCH 11, 2019 TESTED COA SHIP-TO-SHORE CHAT

- SEN Kedougou refueling
    - Secured the AIS transponder and COA Raspberry Pi on board.
    - A ship rider tested COA while the Kedougou transited to and from the fuel pier but software crashed during parsing.
    - Increased AIS power from 1W to 12.5W at the Dakar RADAR Tower location
    - SEN Kedougou and the tower could chat using COA software.
    - Planned to modify the software to prevent AIS parsing errors.
    - Kept COA systems running on the SEN Kedougou and at the Dakar RADAR Tower to detect any software errors.

C.4 MARCH 12, 2019 SOFTWARE BUG FIXES FOR KEDOUGOU AND MUSAMALIYA; INSTALLED COA AT ECR

- Modified software to skip invalid AIS message
    - Sent updates to install on the Gambian vessel.
- Installed COA system in Dakar Navy Headquarters Exercise Control Room (ECR)
    - Navy personnel installed VHF antenna on roof and provided DC power for the AIS transponder. Note, that the COA shared the same power supply with VHF radio system.
- Verified that COA at Dakar RADAR Tower and ECR could transmit and receive chat messages.

C.5 MARCH 13, 2019 RASPBERRY PI HARDWARE PROBLEMS

- Trained Kedougou Ship Rider
    - Trained a U.S. Navy Reservist supporting OE19 on how to operate COA. He was the ship rider on the Kedougou operating both COA and Radar Over AIS.
- Raspberry Pi Hardware Problems
    - While demonstrating COA, there were issues starting the Rocket Chat software that provides the Chat rooms. The COA system from the Dakar Radar Tower system was replaced with a spare system in order to show the ship rider how to operate the system.
- Rocket Chat Corrupted Database
    - The COA system removed from the Kedougou had a corrupt database. Based on a quick internet search, found that users had experienced corruption of their MongoDB, Rocket Chat's database, while using the Raspberry Pi. Raspberry Pi online groups believe that voltage fluctuations may cause Mongo database corruptions.[2]
    - A restoration to the database was attempted which involved reinstalling the Rocket Chat software since the database is bundled with Rocket Chat Software. A connection to the internet could not be established to download a new copy of the Rocket Chat from the network due to modifications made on the Raspberry Pi to make it a hotspot for wireless tablets.
    - After removing the network changes, approximately 5 files, a successful reinstallation of Rocket Chat and the Mongo database was completed.

[2] The database corruption may also have been related to hard disk space on the SD card.

C.6 MARCH 14, 2019 RASPBERRY PI HARDWARE FAILURE AT ERC

- Raspberry Pi SD card corrupted
    - The COA located at the Exercise Control Room, was corrupted when the antenna was removed from the AIS transponder. The COA may have experience a voltage surge when the antenna was removed. The Raspberry Pi was not able to boot from its SD card.
- Replaced the Raspberry Pi on the SEN Kedougou with Laptop Computer
    - After experiencing the voltage problems and noticing the slow response of the Raspberry Pi system, it was decided to replace the Raspberry Pi system on the Kedougou with a laptop running COA. The remainder of the day was spent verifying the laptop had the software modifications and also making the system fool proof for the ship operator. The ship rider tested the COA on the laptop on board the Kedougou before the ship departed to participate in exercises. We returned at 22:00 Z to chat with the ship rider when the Kedougou left the Senegalese Navy Port.
- Ship-to-Shore Chat: Received 1 chat message approximately 1 hour after the Kedougou left the port of Dakar (Figure C-1)

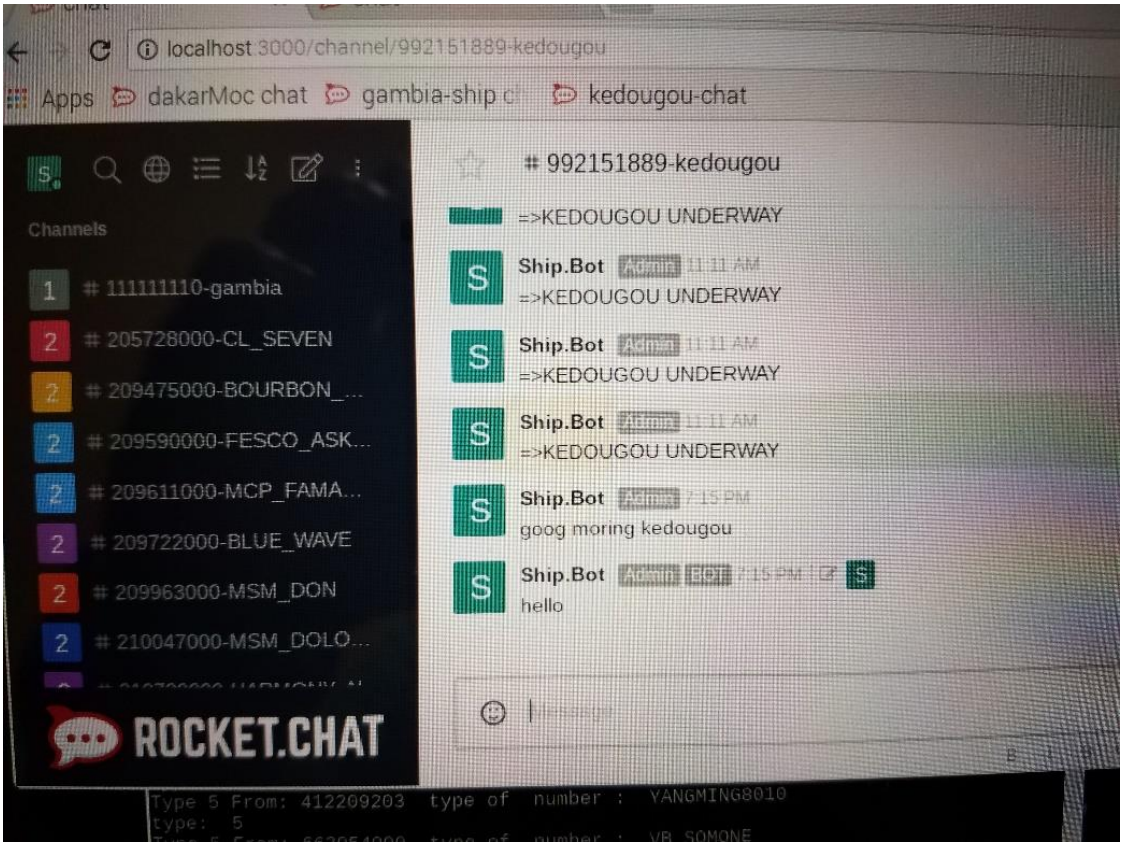


Figure C-1. March 14, 2019 chat message: SEN Kedougou and Dakar Radar Tower.

C.7 MARCH 15 - 16, 2019 REPAIRED RASPBERRY PI SD CARD

- Repaired SD Card
    - The COA system that was removed from the Kedougou. The system was fixed to get the database working again, which required installing scripts and making new accounts. All backup SD cards failed in the Raspberry Pi which was unusual since the same procedure was used to make the spare SD cards as making the original system cards.
- Replaced Raspberry Pi AC power supply with cell phone battery Pack
    - Used an external battery pack to protect COA reinstalled at the Dakar RADAR Tower location but the COA system was still very slow to respond due to memory limitations of the Pi.
    - Overall the Raspberry Pi is not recommended for the COA system due to failure when voltage changes.

C.8 MARCH 17, 2019 RASPBERRY PI OUT OF DISK SPACE, INCORRECT TIME

- Rapsberry Pi out of disk space
    - Turned off type 5 message recording for Pi located in the Dakar RADAR Tower in order to prevent running out of space on the SD card. Type 5 messages are dynamic position reports for ships with VHF range. Also removed any files that were not needed on the Pi to make more disk space.
- Clock not mainted on Raspberry Pi
    - Pi does not have a battery to maintain the clock when system reboots
    - Have to manually reset the date and time when the system is rebooted.
- No Chat messages from SEN Kedougou
    - When the Kedougou arrived back at Dakar Naval Base, the ship rider had been attempting to chat in the RocketChat system but he did not realize that the software had stopped. The software was modified to remove the problem causing COA to crash. A new ship rider was indentified to support the second half of the exercise; he was instructed on how to use COA and also how to manually restart COA if required.
- Rebuilt SD card for Pi
    - This card was used in the COA system installed at St Louis. COA was installed in St. Louis to test communication range of the COA from Shore-to-Shore.
- Drove to St Louis Naval Base
    - Inspected the RADAR system and the potential of using the VHF antenna connected to an existing AIS transponder as an antenna to test COA.

C.9 MARCH 18, 2019 SUCCESS TRANSMITTING AND RECEIVING CHAT MESSAGE FROM DAKAR AND ST LOUIS

- Exchanged chat message from Kedougou at Dakar Radar Tower
    - SEN Kedougou was approximatley 59 nm in (Figure C-5 and C6) Range was based on Kedougou AIS transmission with MMSI of 663095000.[3]
- Chat message between Gambia and Dakar RADAR Tower
    - The Gambian vessel Musamaliya did not have a ship rider. To test the COA the Dakar RADAR Tower sent a chat message and received an acknowledgement message, type 7, from the Gambia vessel. Figure C-7 is a screenshot of the COA receiving a chat message from the Dakar RADAR Tower.[4]
- Chat message between Dakar RADAR Tower and St Louis RADAR Tower
    - Both towers exchanged multiple messages

C.10 MARCH 20, 2019

COA system removed from SEN Kedougou and GAM Musamaliya.

Figure C-2 shows a screen capture of Ship-to-Shore SEN Kedougou and Dakar RADAR Site.

[3] SEN Kedougou turned on this AIS transponder during part of the exercise. Normally, the ship was operating with transmitting their location.

[4] The COA system installed on the Gambian ship, Musamaliya, recorded all chat transactions. Screenshots are from the logs since a ship rider was not onboard to chat.

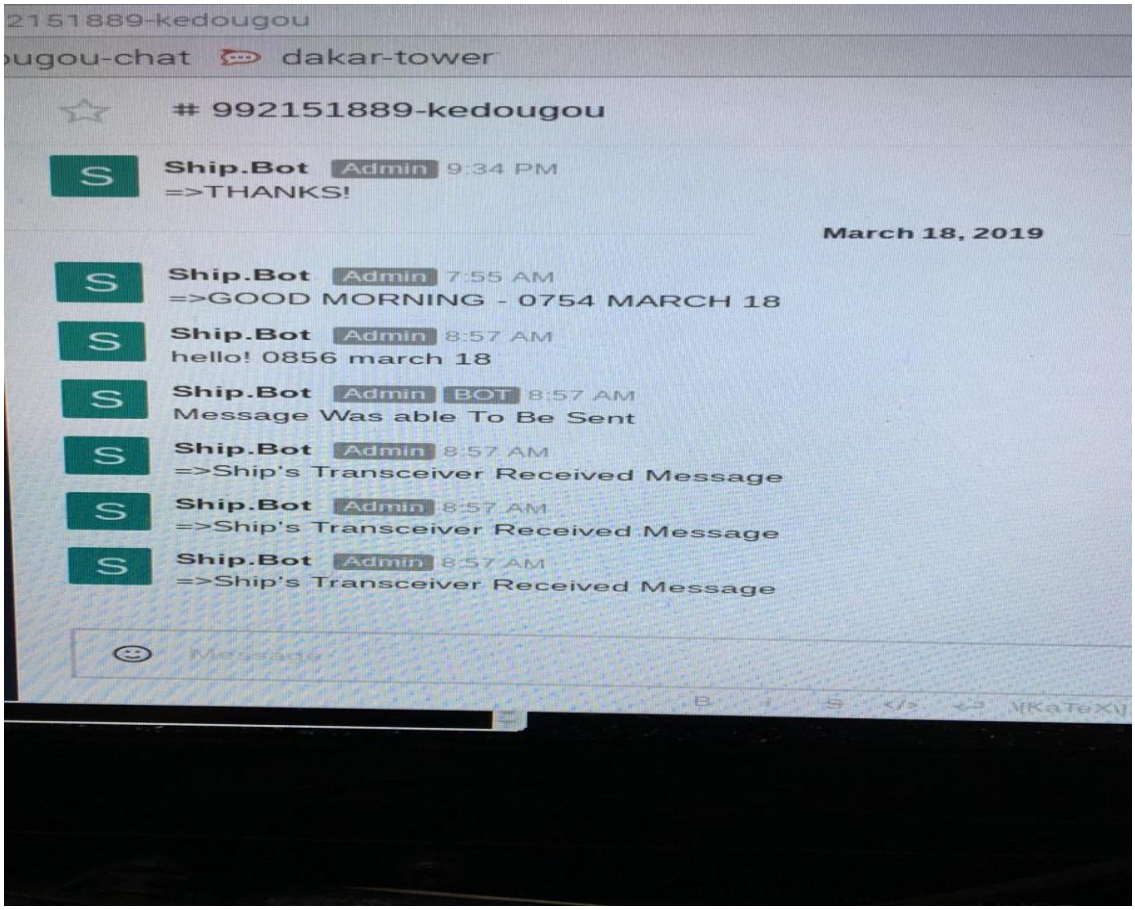


Figure C-2. March 18, 2019 Ship-to-Shore SEN Kedougou and Dakar RADAR Site.

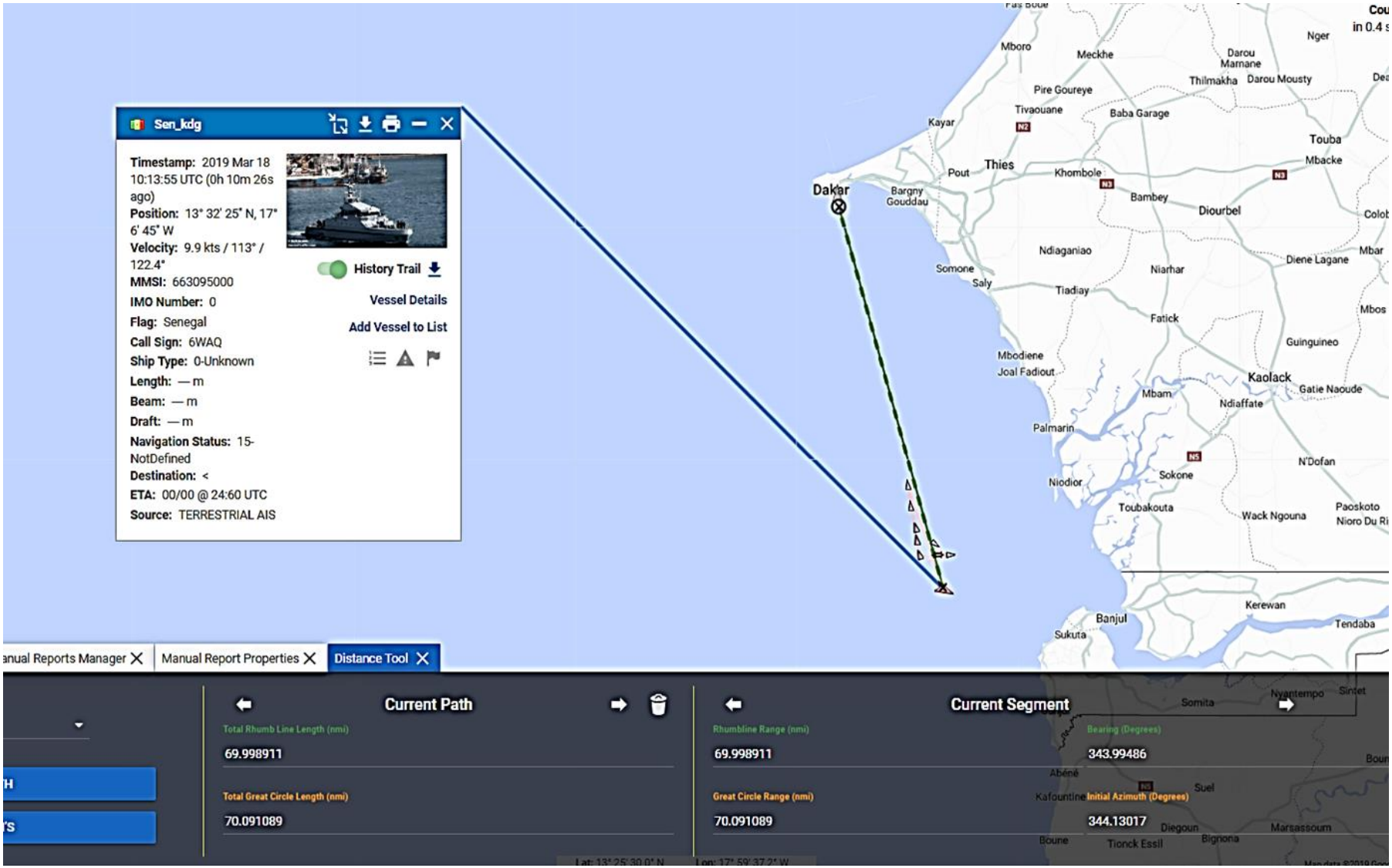
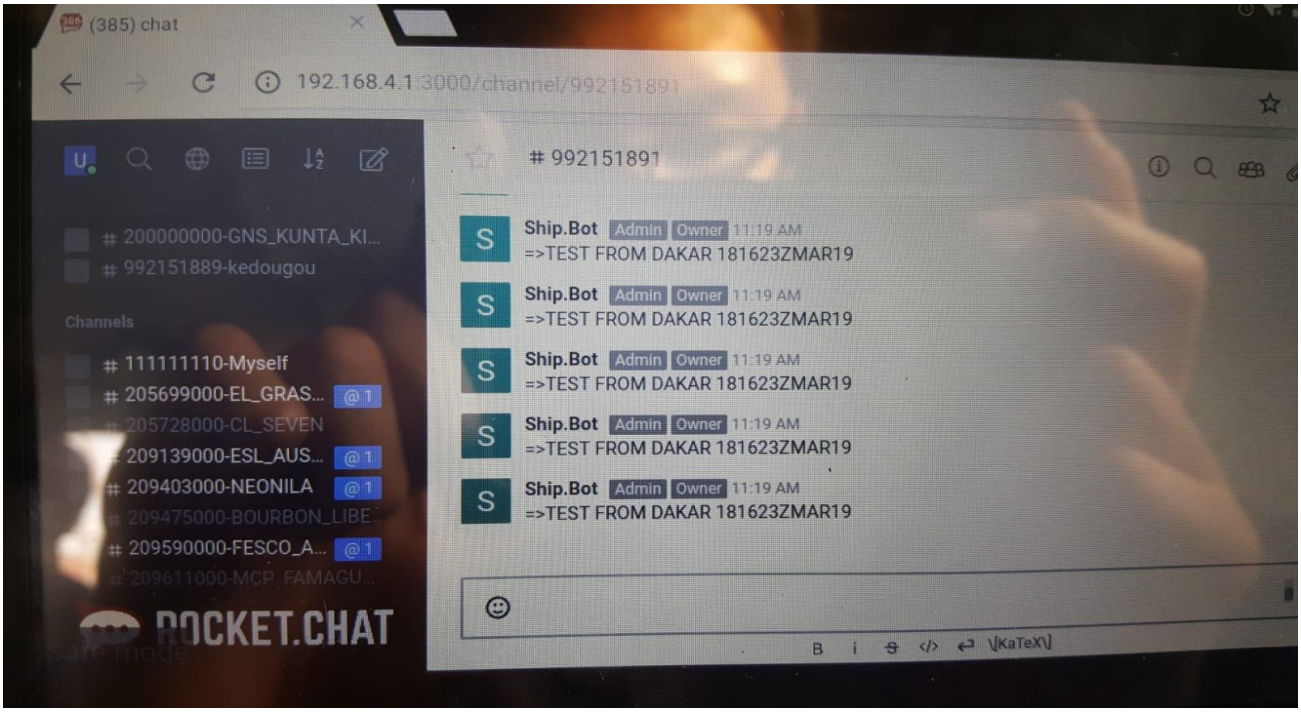


Photo supplied by Google Earth
Location: 59 nm from Dakar

Figure C-3. March 18 10:13 Kedougou History Tracks in SeaVision.



Location: Distance Unknown.

Figure C-4. March 18, 11:19 Chat message from Dakar Tower to Gambia Ship.

C.11 MARCH 19, 2019 SHORE-TO-SHORE TEST AND SHIP-TO-SHIP

- St Louis and Senegal RADAR Tower
  - was able to chat from the St Louis RADAR tower with the Dakar RADAR Tower, (Figure C-5) at an approximate distance of 95 nm (Figure C-6).

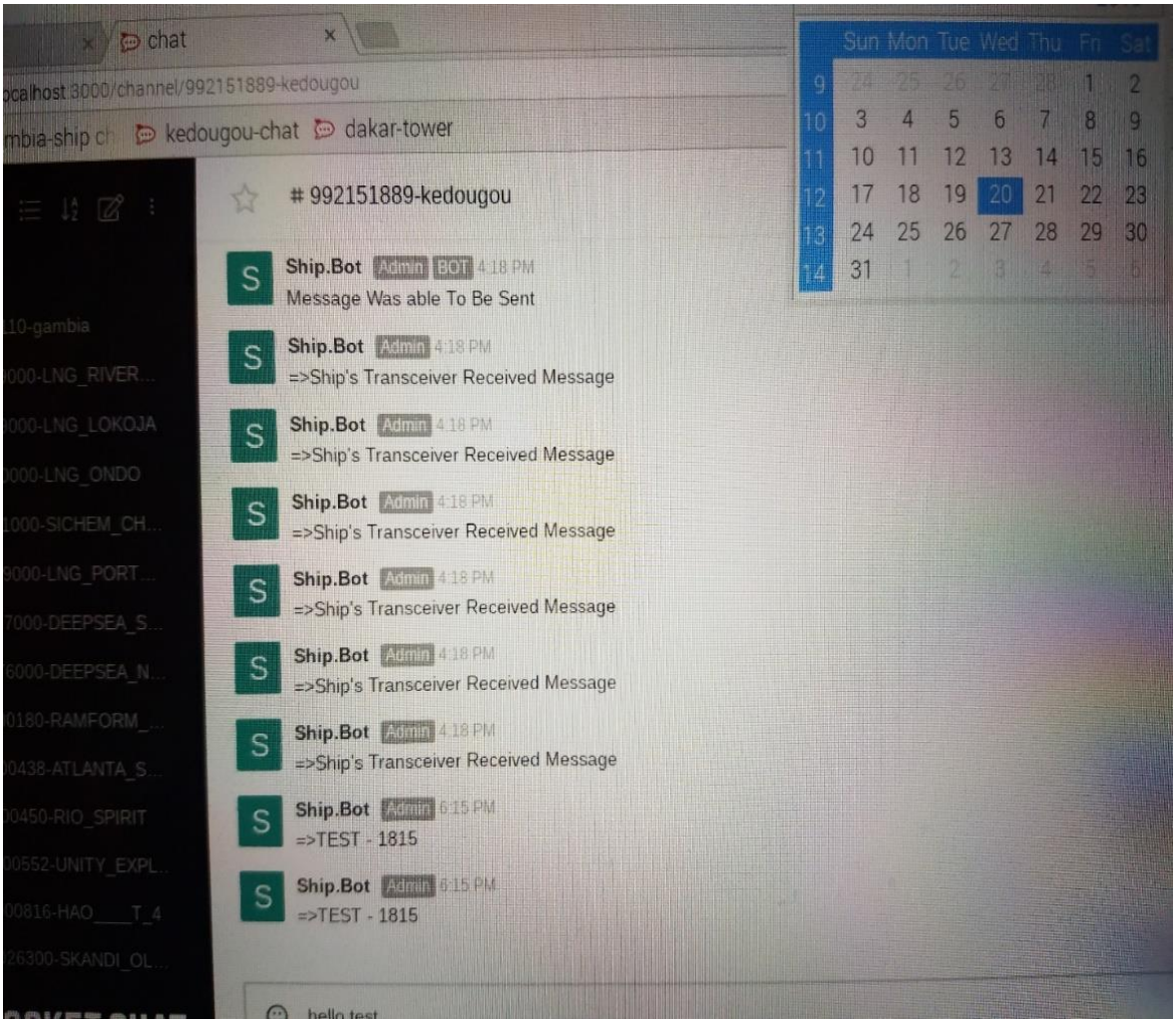
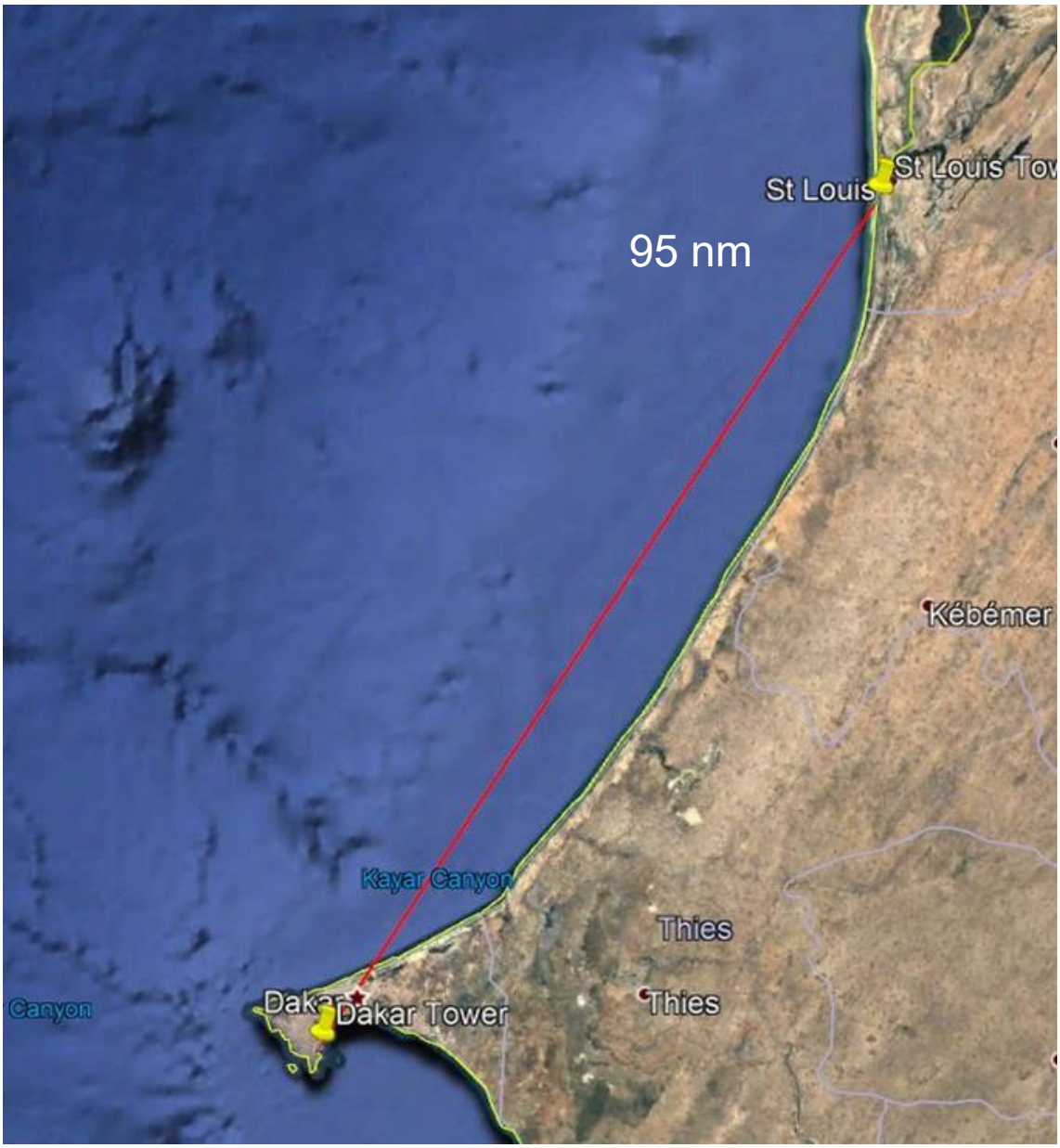


Figure C-5. Chat between Dakar RADAR tower and St. Louis RADAR Tower



- Photo supplied by Google Earth.
- Location: 95 nm from Dakar
- Distance shown as red line.

Figure C-6. Distance from Dakar RADAR Tower to St. Louis RADAR Tower.

APPENDIX D
AIS MESSAGE TYPES:

D.1 TABLE OF AIS MESSAGE TYPES

Appendix D contains a table that details AIS messages and what they mean when they occur during testing, see Table D-1.

Table D-1. AIS Message Types

Type	Message Description
1, 2, 3	AIS Position Report
4	Base Station Report
5	Static and voyage related data
6	Binary addressed message
7	Binary acknowledgement

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1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
October 2020	Technical Report	

4. TITLE AND SUBTITLE

Chat-Over-AIS System Test Report
OBANGAME Express 2019

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

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8. PERFORMING ORGANIZATION REPORT NUMBER

TR 3214

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U.S Naval Forces Europe-Africa / U.S. 6th Fleet
PSC 809 BOX 70
FPO AE 09626-000

10. SPONSOR/MONITOR'S ACRONYM(S)

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14. ABSTRACT

This report focuses on exploring ways to utilize the Automatic Identification System (AIS) in innovative ways to deliver non-AIS data, such as coastal RADAR, using AIS channels. The AIS is an automatic tracking system used on ships and by Vessel Traffic Services (VTS). AIS systems send vessel position reports using dedicated Very High Frequency (VHF) frequencies. While AIS is normally used for collision avoidance, there are other potential uses for AIS that were investigated in our study. Those potential uses are detailed in this report.

Use of the AIS systems as an information conduit channel takes advantage of AIS system capabilities to exchange messages with a custom payload. The payload of the CHAT-over-AIS messages contains chat text messages sent between AIS transponders as a means to relay text data instead of relying on VHF radio for communication between either ship-to-ship or ship-to-shore

15. SUBJECT TERMS

AIS, Chat, MDA

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
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