National Transportation Safety Board
Office of Research and Engineering
Washington, DC 20594

DCA24MM031

VOYAGE DATA RECORDER (VDR) AND OTHER ELECTRONIC DATA

Group Chair's Factual Report

July 14, 2025

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A. ACCIDENT

Location: Baltimore, Maryland
Date: March 26, 2024
Time: 0129 eastern daylight time (EDT)
Vessel: *Dali* (IMO 9697428)
Operator: Synergy Marine Group

B. VOYAGE DATA RECORDER (VDR) AND OTHER ELECTRONIC DATA GROUP

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C. FEDERAL CARRIAGE REQUIREMENTS

Chapter V of the International Convention for the Safety of Life at Sea (SOLAS), regulation 20, specifies voyage data recorder (VDR) carriage requirements. Cargo ships larger than 3,000 gross tons, and all passenger ships regardless of tonnage, must be equipped with a VDR. The VDR for a cargo ship larger than 3,000 gross tons, constructed before July 2002, may be an S-VDR. Either system requires a minimum of the most recent 12 or 48 hours to be stored, depending on the system. In the event of an incident or accident, investigation authorities must be able to download and replay the VDR data without delay. Software, instructions, and special parts necessary for data extraction and replay are required to be contained within the main unit of a VDR.[1]

The *Dali* is a cargo ship constructed after July 1, 2014, and was required to be fitted with a VDR meeting the requirements of IMO resolution MSC.333(90).

[1] Refer to International Maritime Organization (IMO) resolution MSC.214(81) for required download and playback equipment for investigation authorities.

For additional details related to VDR carriage requirements, refer to Table 1 below.

Table 1. Comparison of VDR and S-VDR requirements.

Parameters to be Recorded	VDR after July,1 2014[a]	VDR before July,1 2014[b]	S-VDR[c]
Date and time	X	X	X
Ship's position	X	X	X
Speed	X	X	X
Heading	X	X	X
Bridge audio	X	X	X
VHF communications audio	X	X	X
Radar	X	X	X[d]
AIS	X		X[d]
ECDIS	if fitted		
Depth (echo sounder)	X	X	X[d]
Main alarms	X	X	X[e]
Rudder order and response	X	X	X[e]
Engine and thruster order and response	X	X	X[e]
Hull openings status	X	X	X[e]
Watertight and fire door status	X	X	X[e]
Accelerations and hull stresses	if fitted	X	X[e]
Wind speed and direction	if fitted	if fitted	X[e]
Rolling motion (inclinometer)	if fitted		
Configuration data	X		
Electronic logbook	if fitted		

[a] Refer to IMO resolution MSC.333(90) for required VDR parameters for installations after June 2014.
[b] Refer to IMO resolution A.861(20) for required VDR parameters for installations before July 2014.
[c] Refer to IMO resolution MSC.163(78) for required S-VDR parameters.
[d] S-VDR installations require radar, unless no commercial off the shelf (COTS) interface is available. If COTS interface for radar is not available, AIS data must be recorded.
[e] Certain parameters are only required for S-VDR installations if an IEC 61162 digital interface is available.

SOLAS Chapter V, regulation 18, requires an annual performance test (APT) for VDRs by an approved testing or servicing facility to verify the accuracy, duration, and recoverability of recorded data. Included in an APT is an inspection of devices fitted to aid location of the recorder.

The last APT performed on the *Dali* is provided to this report as attachment 8. In summary, the APT was performed by a marine electronic contractor, Hostmost Engineering Limited, on March 2, 2023.[2] The APT indicated there were no anomalies with the recording of data by the system.

[2] IMO Circular MSC.1/Circ.1222/Rev. 1 allows an operator to conduct the annual performance test on a cargo ship within three months prior to or after the one-year anniversary of the previous test.

The VDR's acoustic beacon expiration date was listed as May 2024 (see Figure 1).

Figure 1. Photo of the VDR acoustic beacon located on the L3 fixed protective capsule mounted above the wheelhouse on the *Dali*. The original insertion battery date, May 2021, is circled. The acoustic beacon is listed with 3 years of durability after insertion.

D. DETAILS OF THE INVESTIGATION

The NTSB Vehicle Recorder Division received the following electronic devices or files:

Recorder Manufacturer/Model:	JRC JCY-1900 VDR
Recorder Serial Number:	MB39751
Device Manufacturer/Model:	ACONIS AMS System
Device Serial Number:	N/A (Electronic File Only)
Device Manufacturer/Model:	Hi-MAP
Device Serial Number:	N/A (Electronic File Only)
Device Manufacturer/Model:	CoCoS-DDS-PMI
Device Serial Number:	Unknown
Device Manufacturer/Model:	iPad Pro (Portable Pilot Unit)
Device Model:	A2069
Device Serial Number:	DMPC90UZNTJ2
Device Manufacturer/Model:	SafePilot CAT XT V4 (Portable Pilot Unit)
Device Serial Number:	8996219
Device Manufacturer/Model:	SafePilot CAT XT V4 (Portable Pilot Unit)
Device Serial Number:	8993978

Electronic File #1:	Alarm.csv (ACONIS AMS)
Electronic File #2:	Trend10s_20240326.mdb (Hi-MAP)
Electronic File #3:	Engine.EDS (CoCoS-EDS)
Electronic File #4:	LR_20240326_0400012_t.eds (CoCoS-EDS)
Electronic File #5:	Dali_and_tugs_–_0525z_to_0526z.xlsx (Made Smart AIS)

1.0 JRC JCY-1900 Description

The Japan Radio Co. (JRC) JCY-1900 VDR is a maritime device designed to record and store critical vessel data in compliance with IMO's MSC.333(90) standards. It captures navigation, propulsion, alarms, weather, radar, and Electronic Chart Display and Information System (ECDIS) imagery, and bridge audio and radio communications data, and other operational parameters, enabling detailed analysis in the event of incidents or for vessel management.[3]

A minimum of 48 hours of data is recorded by the system in the vessel's VDR capsule and a minimum of 30 days must be recorded on the VDR's bridge mounted electronic cabinet. Figure 2 shows the VDR cabinet mounted in an electronic equipment room one deck below the bridge on the *Dali*.

[3] For a record of the audio recorded on the *Dali*, see the Voyage Data Recorder – Audio – Group Chairman's Factual Report, which can be found in the public docket for this investigation.

Figure 2. Photo of VDR cabinet mounted in an electrical room below the bridge on the *Dali*.

The *Dali* was equipped with an L3 fixed protective capsule (model NDH-338) which was mounted above the wheelhouse (see Figure 3). Additionally, the *Dali* was equipped with a Tron 40VDR Float Free capsule unit, which was mounted above the wheelhouse on a deck railing (see Figure 4).

Figure 3. Photo of L3 fixed protective capsule mounted above the wheelhouse on the *Dali*.

Figure 4. Photo of Tron 40VDR float free VDR capsule mounted above the wheelhouse on an exterior deck rail on the *Dali*.

The Automatic Identification System (AIS) is a tracking system used to locate and identify vessels by transmitting and receiving vessel and navigational data on dedicated VHF frequencies with nearby vessels, AIS base stations, and satellites. AIS information includes unique identification, position, course, speed and other characteristics of a ship or station.

The *Dali* was equipped with a Class A JRC AIS transponder (model NTE-183) which was mounted above the wheelhouse on a deck railing (see Figure 5).[4]

[4] The IMO requires Class A AIS transponders on cargo ships greater than 300 tons engaged in international voyages. Class A AIS transponders transmit vessel position reports every 2 to 10 seconds while underway depending on speed and course changes.

Figure 5. Photos of AIS transponder mounted above the wheelhouse on an exterior deck rail on the *Dali*.

1.1 JRC JCY-1900 Data Extraction

In order to access VDR data, raw VDR data were downloaded from the ship's VDR. This can be accomplished in two ways, one, using the JRC JCY-1900's bridge mounted USB VDR console, or using an ethernet connection to the VDR cabinet mounted below the bridge (see Figure 6 and Figure 2, respectively).[5]

[5] The VDR cabinet is the long-term recording medium as defined in IMO Resolution MSC.333(90).

Figure 6. Photo of the JCY-1900 Operation Panel Unit mounted on the *Dali*'s bridge console.

Initially, during the post-accident on-scene response, six-hours of data around the time of the accident were downloaded using the bridge mounted USB console (00:00 EDT to 06:00 EDT). The download process for the raw VDR data took approximately one hour to complete.

After the initial download was completed, the manufacturer software was used for the playback. Figure 7 is a screen capture of the VDR playback window. Limited parameters and audio were reviewed. The Voyage Data Recorder – Audio – Group Chairman's Factual Report which is located in the investigation docket, details some of the limitations of the playback software.

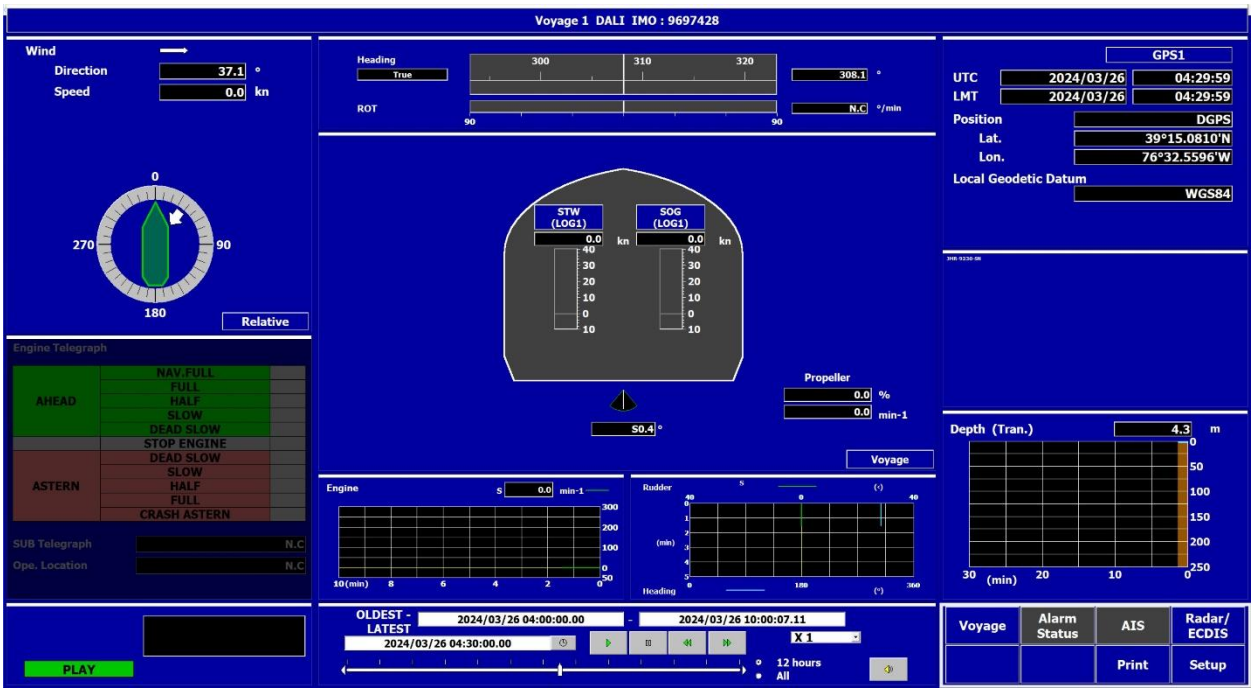

Figure 7. A screen capture of the JRC JCY-1900 playback software.

The download process, whether by means of the USB port on the bridge console or the ethernet connection in the VDR cabinet, results in parametric data, bridge audio, and image data extracted in a proprietary format.

Parametric data files were output as .log files. The log files were converted into the National Marine Electronics Association (NMEA) 0183 format using the VDR manufacturer software. Lab software was used to convert the NMEA formatted data into engineering units in a comma-separated value (CSV) format.

Electronic Chart Display and Information System (ECDIS) and Radar images from the bridge were output as proprietary .DAT files. Using the manufacturer's software, the .DAT files were converted into .png files for each display.

Two days following the accident, a marine electronics technician certified to service JRC VDRs was provided to the NTSB by the ship's operator. The marine electronics technician attempted to perform an ethernet cable download of the entire contents of the ship's VDR.[6] The marine electronics technician was unable to perform a successful retrieval of all VDR data from the ship's VDR cabinet. On March 29, 2024, the NTSB removed the electronic memory components from the *Dali*'s VDR long-term storage medium (see Figure 8). In consultation with JRC, a plan was constructed to download the contents at JRC Americas office in League City, Texas.

[6] IMO Resolution MSC.333(90) stipulates 30 days of data must be available from the long-term recording medium. In this case, the VDR indicated that 37 days of data were available.

On April 15, 2024, two specialists from the NTSB's Vehicle Recorder Laboratory traveled with the VDR memory components to JRC Americas in League City, Texas. At this facility, the VDR memory components were installed in an exemplar VDR system and a full download was attempted (see Figure 9). The download took 36 hours and was accomplished using the ethernet transfer method and JRC proprietary software and approximately 37 days of VDR data were recovered.

Figure 8. Photos of JCY-1900 internal memory components: main control board (see left photo) and audio recording board (see right photo).

Figure 9. Photo of the internal memory components placed into a surrogate JCY-1900.

1.2 JRC JCY-1900 Recording Description

The data extracted from the VDR included information from February 21, 2024, through March 29, 2024, UTC. Data from the time surrounding the March 26, 2024, accident were recorded by the VDR. Standard IEC 61162 VDR parameters were sampled approximately every second (1 Hz). VDR Heading data from the gyro compass were sampled approximately every 0.2 seconds (5 Hz).

The rate of turn parameter was extracted from the VDR's !AIVDO sentence.[7] The rate of turn rate recorded approximately every 1 second (1 Hz).

The VDR was interfaced to record ACONIS alarms.[8] The alarms had variable sample rates.

The VDR also captured alarms related to the *Dali*'s bridge navigational watch alarm system (BNWAS). The system included recorded information for various alarms and fire doors.

The system was also designed to record image data of *Dali*'s ECDIS, X-Band radar, and S-Band radar displayed to the crew on board the *Dali*'s bridge. Images were captured approximately every 15 seconds.

The VDR parameters evaluated for this report appear to not be in accordance with the VDR carriage requirements. According to the IMO resolution MSC.333(90), the VDR should record engine and thruster order and response. According to section 5.5.12, the recording should include thrusters, if fitted, and indicate the control station in use. The data extracted from the VDR showed an invalid mode indicator for thruster RPM demand and response. The values for thruster RPM demand and response had no data.

Audio extraction information for the JRC JCY-1900 VDR system can be found in the Voyage Data Recorder – Audio – Group Chairman's Factual Report located in the investigation docket.

1.3 JRC JCY-1900 Time Correlation

Each data source operated on its own clock, therefore the data sources needed to be correlated to each other using common events recorded on each source. The VDR contained the most comprehensive data set and external references to universal time coordinated (UTC).

[7] The !AIVDO sentence contains own ship data transmitted from the ship through the AIS system.
[8] The ACONIS system is an alarm monitoring system that monitors the main propulsion, power generation, and auxiliary systems on the vessel.

Timing of the VDR data was synchronized to global positioning system (GPS) time and was recorded in UTC. Time was converted to local time, eastern daylight time (EDT) by subtracting 4 hours from the timestamp.

The VDR recorded and time stamped various NMEA messages that contained parameters such as position, heading, course, speed, etc. Two NMEA messages contained a UTC time stamp within the message, the $GPZDA message and the $GPGGA message. The $GPZDA message contained a UTC year, month, day, hour, minute, and second time stamp. The VDR clock was synchronized to this time stamp to the closest second. The VDR clock and $GPZDA timestamp were selected as the master clock for this investigation.

The $GPGGA message contains GPS position data and a UTC hour, minute, and second time stamp. The $GPGGA time stamp was approximately 29 seconds behind the $GPZDA and VDR clock time stamp. This timing discrepancy was not resolved, however, shore-based AIS receivers recorded *Dali*'s broadcast AIS position contained in the $GPGGA message concurrent with the $GPZDA time.

Onboard the *Dali*'s bridge, a time sync check was completed comparing local time (EDT) to the time displayed on the radar and ECDIS stations. The display time on the images did not sync with the $GPZDA time. Figure 10 shows EDT compared to the time displayed on the radar and ECDIS images. The primary radar display showed an offset of 03:59:57. The primary ECDIS display showed an offset of 09:28:47. These offsets were used to determine the local time on the extracted radar and ECDIS images from the VDR.

Figure 10. Photos of time sync verification on the *Dali* for the radar image (see left photo) and ECDIS image (see right photo) on March 26, 2024 EDT.

Additional ECDIS images were taken during the ECDIS playback onboard the *Dali*. The time displayed on the ECDIS image during playback did not sync with the $GPZDA time. Position data from extracted VDR images were used as guide when converting the playback time to EDT. Approximately 1 minute and 1 second was added to playback time to convert the displayed time to EDT.

2.0 ACONIS Alarm Monitoring System (AMS) Description

The *Dali* is equipped with an Advanced Control and Integration System (ACONIS). This system monitors main propulsion, power generation, and auxiliary systems on the vessel. ACONIS is equipped with human to machine interface (HMI) stations, which allow operators to control functions of the machinery, view equipment running status and levels, and acknowledge alarms. The HMI stations display mimic diagrams to the operators.[9]

The ACONIS system is also equipped with an Alarm Monitoring System (AMS). The AMS alerts operators when monitored equipment falls outside of a preset limit. Operators can acknowledge alarms through a keyboard or the mimic page. The AMS also retains historical alarm events, and historical monitored values.

The ACONIS alarm display shows 30 lines per page and arrange the events occurred in chronological order (see Figure 11). In the alarm display, the tag name in which the alarm occurred, the time when the event occurred, the present measurement value, alarm high limit value, and alarm low limit value can be shown, and the unacknowledged alarm blinks according to the user's handling situation.

2.1 ACONIS AMS Data Extraction

An ACONIS alarm printout and electronic file were provided to the NTSB. The data provided the historical timeline of the alarms displayed on the ACONIS console by local time (see Figure 11).

The ACONIS signals were also interfaced to the VDR by a RS-422 serial link, in accordance with IEC 61162-1. Laboratory software was used to extract the ACONIS alarm condition and its current state of acknowledgement.

2.2 ACONIS AMS Recording Description

The ACONIS system recorded various engine and electrical alarms which included alarms related to the auxiliary boiler, bilge, generator, fire system, and steering gear systems. ACONIS alarms related to the steering gear system are included in this report.

[9] Mimics are visual pages allowing the operator to monitor various ACONIS systems.

2.3 ACONIS AMS Time Correlation

The ACONIS system was not connected to a valid time source and its time clock was not valid. When the HR1 and LR1 breakers opened, all three steering pumps lost electrical power. This was indicated on the ACONIS panel with “NO.1 S/G NO VOLTAGE,” “NO.2 S/G NO VOLTAGE,” and “NO.3 S/G NO VOLT” alarms (see Figure 11). The time stamp on these alarms was 01:23:39. Post-accident testing showed that there was an approximate 3 second delay from the loss of electrical power to the steering pump to when the aural began and the alarm message registered on the ACONIS panel. Testing also showed that when the no voltage condition was corrected the timestamp appeared in the “NORMAL DATE TIME” column with no delay.

The ACONIS system logged alarms as both UTC and local time. ACONIS local time was changed to EDT using a time sync check to EDT, by adding 1 minute, and 26 seconds. After the approximate 3 second delay is subtracted, the result conversion to get ACONIS data from local to EDT was adding 1 minute, and 23 seconds.

The ACONIS data recorded by the VDR had two timestamps in the sentence format. The first timestamp captured the UTC time when ACONIS alarms were recorded by the VDR. The second timestamp captured the time when an ACONIS alarm condition changed. Both timestamps were compared and did not match. The timestamp that captured the alarm condition change was compared to the ACONIS alarm electronic file and both timestamps matched.

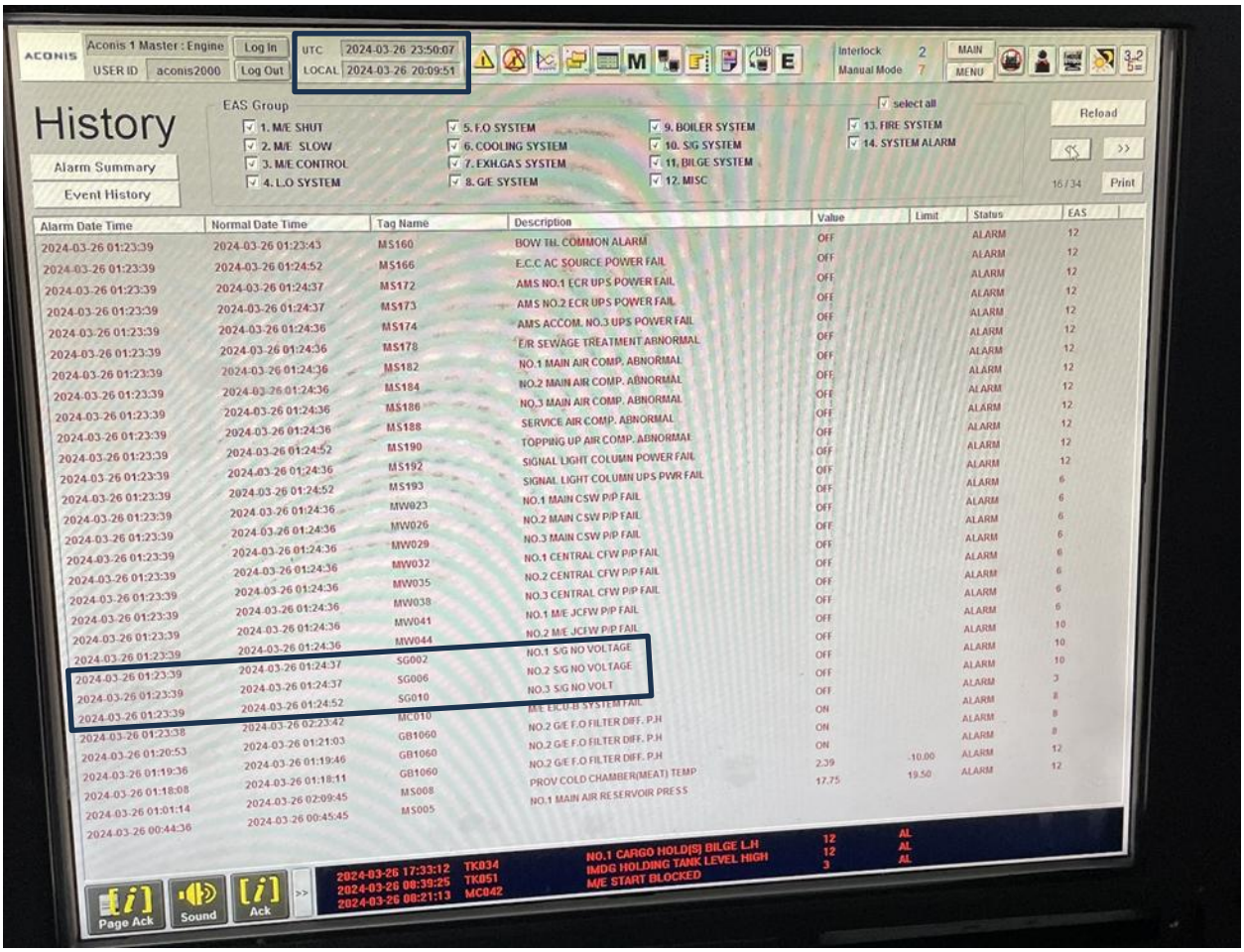

Figure 11. ACONIS panel showing steering pump voltage alarms (annotated) and the timestamps.

3.0 Hyundai HiMAP Description

Hyundai Intelligent Measuring and Protection Device (HiMAP) is a multifunctional digital protection relay that protects incoming and feeder lines, the motor, and the transformer.

It also has various kinds of measuring functions to check synchronization and a communication function for the Power Management System (PMS) to supervise operating conditions. It has limited device logging capabilities.

Hyundai HiMAP data records data related to the four diesel generators (DG).

3.1 Hyundai HiMAP Data Extraction

Microsoft Access files of the HiMAP historical data were provided to the NTSB. The 10-second trend files were converted to CSV format using laboratory equipment.

3.2 Hyundai HiMAP Recording Description

HiMAP data mainly provided data related to the generators. Electrical data related to the four diesel engines are included in this report.

3.3 Hyundai HiMAP Time Correlation

The HiMAP data in the electronic file appeared as ACONIS UTC time. The UTC conversion to EDT was calculated using two conversions. First, ACONIS UTC was changed to ACONIS local time by subtracting 03:40:16, the difference between UTC and local time (see Figure 11). Second, ACONIS local time was changed to EDT using a time sync check to EDT, adding 00:01:26. The result conversion to get HiMAP ACONIS data from UTC to EDT was subtracting 3 hours, 38 minutes, and 50 seconds.

4.0 CoCoS-EDS Description

The Computer Controlled Surveillance – Engine Diagnostic System (CoCos-EDS) is a maintenance support tool associated with MAN Diesel engines that facilitates engine surveillance and operational performance indicators that aid in fault diagnosis. The system logs, monitors, and stores engine performance data and trends.

4.1 CoCoS-EDS Data Extraction

Electronic files of CoCoS-EDS logs were provided to the NTSB by representatives of Hyundai, performing work under NTSB supervision. Manufacturer software was used to examine CoCoS-EDS Data. A Parquet viewer was used to convert the parquet files into CSV files.

4.2 CoCoS-EDS Recording Description

Data related to engine RPM and engine RPM setpoint are included in this report. Both engine parameters were recorded approximately every 1 second (1 Hz).

4.3 CoCoS-EDS Time Correlation

Using the VDR engine RPM parameters as a common benchmark, timing of the CoCos-EDS data was converted to EDT by subtracting approximately 11 hours, 38 minutes, and 16 seconds from the timestamp.

5.0 Portable Pilot Unit (PPU) Description

The PPU is a computer system used by pilots for navigating waterways. The PPU can act as a personal, standalone AIS display, for situational awareness. Typically, while piloting two receivers are used to show the position and movement of a vessel

in real time. One receiver acts as a Global Navigation Satellite System (GNSS) and is typically mounted on the bridge wing where it has a clear view of the sky. The other receiver connects to the ship's AIS pilot plug inside the bridge and transmits AIS data collected from this port via Wi-Fi to the pilot's connected tablet. This receiver also contains a compass and rate sensor which provides more precision in ownship heading and rate of turn than is available through the AIS system. Depending on the software configuration, the PPU may log data that can be replayed after a voyage. According to the Senior Maryland Pilot, the GNSS receiver in use during the accident voyage did not pick up a signal and only the AIS interface was used.

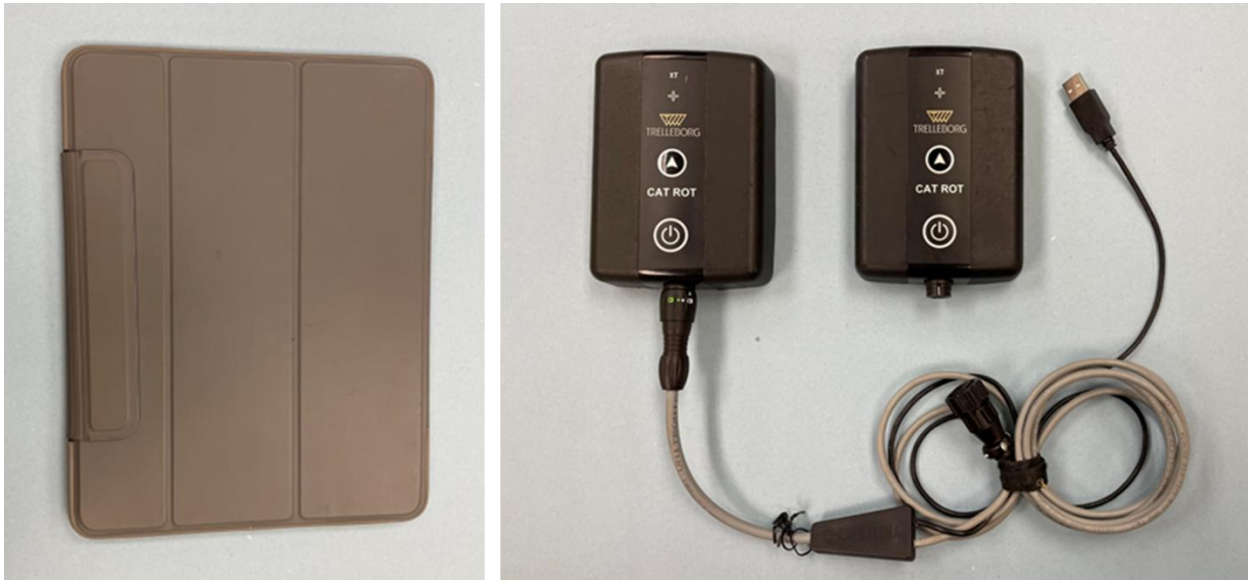

Figure 12. Photos of Portable Pilot Unit include an Apple iPad Pro (see left image) and Trelleborg SafePilot GNSS rate sensor receivers (see right image).

5.1 Portable Pilot Unit (PPU) Data Extraction

The pilot's Apple iPad Pro and combined rate sensor and GNSS receivers were quarantined by the Association of Maryland Pilots (AMP) and were later provided to the NTSB lab. These units are shown in Figure 12. A forensic image of the iPad Pro was made.

On April 11, 2024, two specialists from the NTSB Vehicle Recorder Laboratory traveled with the PPU to AMP in Baltimore, Maryland. At this facility, technical support staff provided by AMP assisted in the examination. The iPad Pro was running the SafePilot application by Trelleborg Marine Systems Denmark A/S, version 22.0.1.[10]

SafePilot log files were recovered and reloaded into the SafePilot application for playback and review. The playback video of the accident route was also captured

[10] SafePilot is a maritime piloting and navigating software. The software provides electronic chart displays that show position, heading, speed, course over ground, and rate of turn in real time. Data may be logged and replayed after a voyage.

and is attached to this report as attachment 6. A portion of the logs also included recorded AIS messages, which were decoded using laboratory software.

5.2 Portable Pilot Unit (PPU) Recording Description

The SafePilot log files contained AIS !AIVDO and !AIVDM sentences, as well as individual NMEA sentences for true heading and rate of turn.[11]

On March 26, 2024, the standalone GNSS receiver was not able to acquire a GNSS signal, and the pilot was only accessing AIS data through the pilot plug. On July 17, 2024, the Vehicle Recorder Division tested the iPad Pro and both GNSS rate sensor receivers. Testing revealed both receivers were able to provide satellite-based augmentation system (SBAS) and GNSS to the iPad. No anomalies were observed during testing.

5.3 Portable Pilot Unit (PPU) Time Correlation

The extracted timestamp from the PPU AIS did not contain a full timestamp and only contained seconds after the minute recorded within each AIS position report message. Recorded true heading and rate of turn parameters did not have a timestamp.

The time displayed on the PPU playback matched the authoritative VDR time, and no timing offset was created.

6.0 Made Smart AIS Electronic File Description

Made Smart is a commercial AIS supplier, which provides vessel AIS tracking and plotting of vessel positions for the global maritime industry. AIS information includes unique identification, position, heading, course, rate of turn, and speed of a ship or station.

6.1 Made Smart AIS Electronic File Extraction

An electronic file of the Made Smart AIS data of *Dali*, and tugboats, *Bridget McAllister* and *Eric McAllister* were provided to the NTSB Vehicle Recorder Division.

6.2 Made Smart AIS Electronic File Description

Made Smart AIS data contained the *Dali*'s dynamic AIS information and static data. The AIS information had variable sample rates, the average was approximately 10 seconds per sample (0.1 Hz).

[11] !AIVDO sentences are used to transfer own ship AIS message packet, as defined in ITU-R M.1371. !AIVDM sentences contain other ship data transmitted and received on the VHF Data Link (VDL).

6.3 Made Smart AIS Electronic File Time Correlation

Made Smart AIS data were recorded in UTC. Time was converted from UTC to EDT by subtracting 4 hours from the timestamp.

7.0 ECDIS Display Description

The JRC Electronic Chart Display and Information System (ECDIS) is a navigation system that provides real-time chart-based situational awareness by integrating electronic nautical charts with data from onboard sensors, such as GPS, AIS, and radar. These units are designed to meet IMO regulations and serves as a replacement for paper charts, offering automated route planning, chart updates, and navigational overlays. JRC ECDIS units are used on a range of vessels. The system assists mariners in maintaining safe navigation by displaying vessel position, surrounding traffic, and navigational hazards in a clear, electronic format.

On the primary navigation station on the *Dali,* there were five JRC Multi-Function Displays (MFDs), which each MFD being labeled as having a different purpose (Backup ECDIS, radar, etc).

7.1 ECDIS Display File Extraction

Upon NTSB's arrival to the *Dali*'s bridge on the day of the accident, a handheld video recording of the MFD configured as the primary ECDIS playback was captured. That playback file included ship position information for approximately 54 seconds of the blackout. Additionally, personnel from the USCG performed a USB download of the *Dali's* ECDIS display on the day of the accident. The USB drive was transferred to NTSB custody. The NTSB elected to have JRC perform a readout and playback of the ECDIS data from the USB storage device during the visit on April 15, 2024. The playback was performed using an exemplar JRC ECDIS at the facility. An inline screen capture device was attached to the ECDIS to perform a playback capture.

7.2 ECDIS Display File Description

The video captured on the day of the accident by NTSB personnel is attached to this report as attachment 7. This video includes approximately 54 seconds of ship's data which could have been displayed to the crew during the blackout. This version of the playback data was most representative to what could have displayed on the ECDIS during the accident event.[12]

[12] The playback performed at the JRC America's facility differed from the playback on board the ship. This playback displayed a different chart overlay, did not show the ownship outline of the *Dali*, and did not capture some of the position data that the was present during the blackout. For this reason, the captured playback made during the visit to JRC Americas was not used in this investigation and is not attached to this report.

During a loss of ship's AC power, the MFD units are designed to power from a battery backup. The battery power source is located under each MFD module. JRC supplied a test procedure to verify the MFD display settings during a simulated blackout condition. In the MFD installation menu, an option can be configured to either turn the MFD display off, or to dim the display in the event of the loss of ship power while on the operation of the MFD backup battery. Post accident testing on May 15, 2024, showed four of the five displays were configured to power off the MFD LCD display during an AC power failure event (see Figure 13). Additionally, the MFD cabinets were inspected for the presence of an MFD backup battery as well as the battery's functionality. Each MFD console contained a backup battery, however, it was determined that a voltage measurement of each battery would not be representative of the condition of the batteries during the accident event, since 50 days had passed since the event.

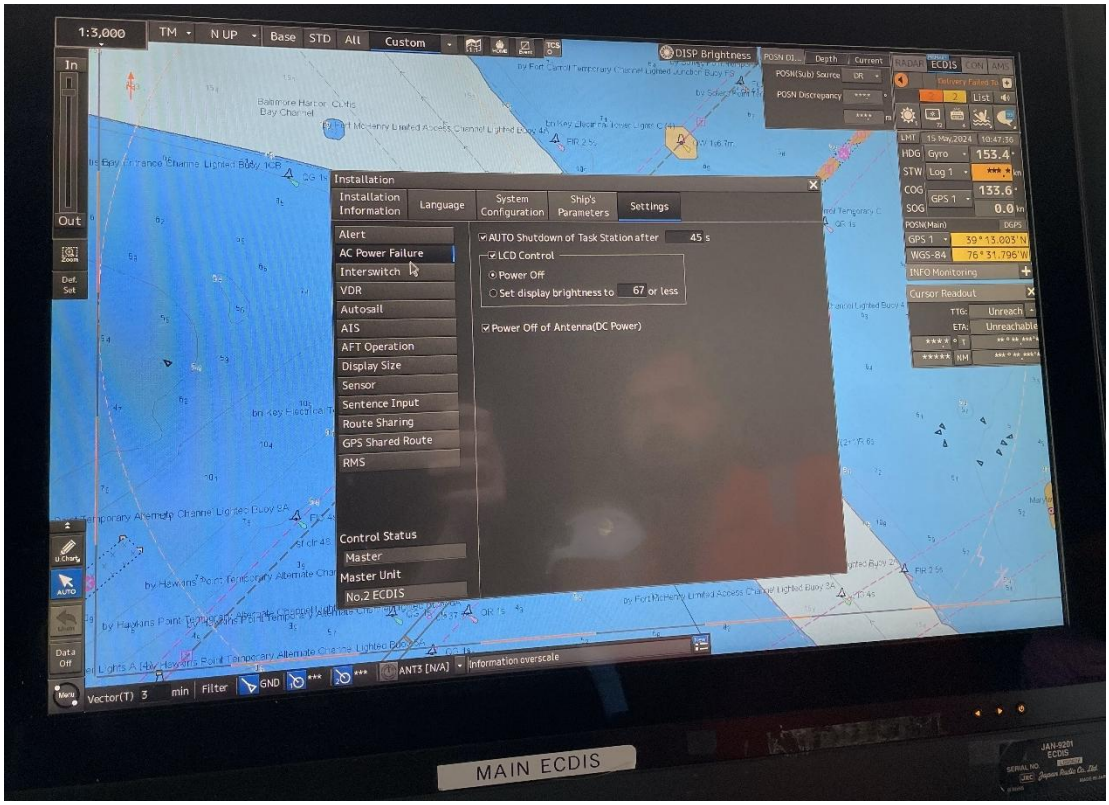

Figure 13. Photo of Main ECDIS AC power failure settings (crewmember reflection redacted).

SOLAS requirements discuss the functionality requirements of ECDIS systems during a power interruption. The requirements state, *"It should be possible to operate ECDIS and all equipment necessary for its normal functioning when supplied by an emergency source of electrical power…"* however, the SOLAS requirements do not explicitly require the use of a backup battery or discuss any specific performance requirements of back up battery systems.[13]

[13] IMO Resolution MSC.232(82)

7.3 ECDIS Display Time Correlation

Each ECDIS display had a different timing offset to the authoritative VDR clock. The ECDIS captured in the video recording (attachment 7), had a time offset that was approximately 1 minute and 1 second behind the VDR's clock. Note that the times shown in each ECDIS and Radar figure (Figures 29 to 172 and Figures 181 to 182) do not have a time correction applied and are displayed in an as recorded time state.

E. DATA SUMMARY

JRC JCY-1900

The data extracted included approximately 37 days of parametric data, beginning on February 21, 2024, at 0300 UTC and going to March 29, 2024, at 1459 UTC. The data from the time period of 00:30:00 EDT to 01:31:00 EDT on March 26, 2024, were determined to be of interest and are included in this report.

Figure 14 to Figure 17 are plots containing parameters recorded by the VDR. from 00:30:00 EDT to 01:31:00 EDT.

Figure 19 to Figure 22 are plots of the same parameters from 01:24:00 EDT to 01:30:30 EDT. After the first blackout, the Rudder angle demand parameter experienced two instances of invalid data from 01:27:08 EDT to 01:27:14 EDT and 01:27:40 to 01:27:48 EDT.

Figure 24 to Figure 27 are plots of the same parameters around the time of the accident from 01:28:00 EDT to 01:29:30 EDT.

The VDR parametric data experienced an outage starting at 01:24:58.7 EDT when the rudder sensor angle parameters and the rudder angle demand parameter stopped recording.[14] At this time, the recorded rudder sensor angle transducer was 0.2 degrees starboard. All other parametric data and display images stopped recording at 01:25:03.2 EDT. Prior to the outage at 01:25:03, the speed over ground was 8.9 kts and engine speed was 34.9 RPM, the heading was 141.7 degrees, the course over ground was 140.8 degrees, and the rate of turn was 0.7 degrees per minute starboard. All heading referenced in this report are true heading. Parametric data and display images resumed recording again at 01:26:01.7 EDT. At this time, the speed over ground was 8.5 kts and engine speed was 0 RPM, the heading was 144.2 degrees, the course over ground was 142.7 degrees, the rudder sensor angle was 0.2 degrees starboard, and the rate of turn was 5.4 degrees per minute starboard.

[14] According to the Voyage Data Recorder – Audio – Group Chairman's Factual Report, the sound of the Automatic Power Change Over Circuit was audible operating at 01:24:59.2 EDT.

The *Dali* contacted the Francis Scott Key Bridge at approximately 01:29:09 EDT. At the time of contact, the speed over ground was 6.4 kts, the engine speed was 0 RPM, the heading was 159.5 degrees, the course over ground was 158.1 degrees, the rudder sensor angle was 35.6 degrees port, and the rate of turn was 3.6 degrees per minute port.

Figure 16, Figure 21, and Figure 26 are plots of parameters containing thruster information. The thruster operating location was recorded as the starboard wing. The thruster RPM demand and response mode indicators were invalid and no data were recorded from 00:30:00 EDT to 01:31:00 EDT. The thruster pitch demand was 0 degrees and the thruster pitch response varied around 0.5 degrees port. Thruster pitch demand and response during the accident voyage did not show any activity, however thruster pitch demand and response did show activity during undocking from Portsmouth, Virginia and docking at Seagirt Terminal in Baltimore, Maryland on March 23, 2024.

Figure 15, Figure 20, and Figure 25 show additional VDR parameters. Two serial channels provided water speed and ground speed data to the VDR. Channel 4 provided data from the Consilium Sal T2 speed log. Channel 9 provided ground speed from the JLN-720 Satellite Log. At approximately 01:27:04 EDT until to 01:27:58 EDT parameters, longitudinal ground speed, transverse water speed, and stern transverse ground speed, from the speed log were not recorded and had a data invalid status. The data resumed and at approximately 01:28:30 EDT these parameters were not recorded and remained not recorded. For the entire accident recording, the status for parameters, transverse water speed and stern transverse water speed, were invalid data and no data were recorded.

The parameter, water depth relative to the transducer recorded in meters and the parameter was converted to feet. Water depth was not recorded from 01:28:44 EDT to 01:28:59 EDT. Prior to the parameter outage, the water depth was 3.9 feet. When the water depth parameter resumed the reading was approximately 166 feet. During the bridge contact, water depth was approximately 169 ft. At 01:29:32 EDT the parameter was not recorded and remained not recorded.

The corresponding tabular data from the VDR which were used in this report are provided in electronic CSV format as attachment 1 to this report.

Figure 29 to Figure 172 contain ECDIS and radar images extracted from the VDR from approximately 01:06:51 EDT to 01:24:46 EDT. The ECDIS images were captured at a rate of once about every 15 seconds, and the radar images were captured at a rate of about once every 15 seconds. Figures 28 to 171 encompass the majority of the accident voyage. A more detailed description follows.

Figure 29 to Figure 48 show the *Dali* entering the Fort McHenry Channel from approximately 01:06:51 EDT to 01:09:15 EDT. During this time, tugboats *Bridget McAllister* and *Eric McAllister* are shown letting go (see Figure 52).

Figure 173 to Figure 180 contain additional ECDIS images captured during the ECDIS playback onboard the *Dali* from 01:24:51 EDT to 01:25:53 EDT - when ECDIS images were not recorded to the VDR. Figure 175 to Figure 180 show warnings of AC power failure and lost antenna control from approximately 01:25:11 EDT to 01:25:53 EDT.

Figure 181 and Figure 182 are the last X-Band and S-Band radar images captured by VDR before the contact with the Francis Scott Key Bridge, from approximately 01:25:56 EDT and 01:26:02 EDT. Both images show a blank radar overlay and lost antenna control message.

Full resolution S-Band radar, X-Band radar, and ECDIS images are provided in the public docket as attachment 2 through attachment 5 to this report. Additionally, the ECDIS playback video are provided as attachment 7 to this report.

ACONIS AMS

Steering gear alarms from the ACONIS system were overlayed on the ACONIS steering gear alarms captured by the VDR along with the rudder sensor angle for reference. These steering gear alarms are found on Figure 17, Figure 22, and Figure 27 of the VDR data plots.

Hyundai HiMAP

Data of the four diesel generators from the accident date are annotated on Figure 18, Figure 23, and Figure 28. These annotations appear as text boxes with arrows.

CoCoS-EDS

CoCos-EDS data provided additional engine RPM data during VDR parametric data outage period. Data from the CoCos-EDS were overlayed on VDR plots in Figure 14, Figure 16, Figure 19, Figure 21, Figure 24, and Figure 26.

Made Smart Automatic Identification System (AIS)

Data from Made Smart AIS provided additional data during VDR parametric data outage period from 01:25:03.2 EDT to 01:26:01.7 EDT. AIS parameters, speed over ground, heading, course over ground, and rate of turn were overlaid on the VDR plots in Figure 14, Figure 16, Figure 19, Figure 21, Figure 24, and Figure 26.

Portable Pilot Unit (PPU)

A playback video of the accident from 00:20:00 EDT to 01:30:52 EDT is provided in MP4 format as attachment 6 to this report.

Submitted by:

Matthew Yandrick
Recorder Specialist

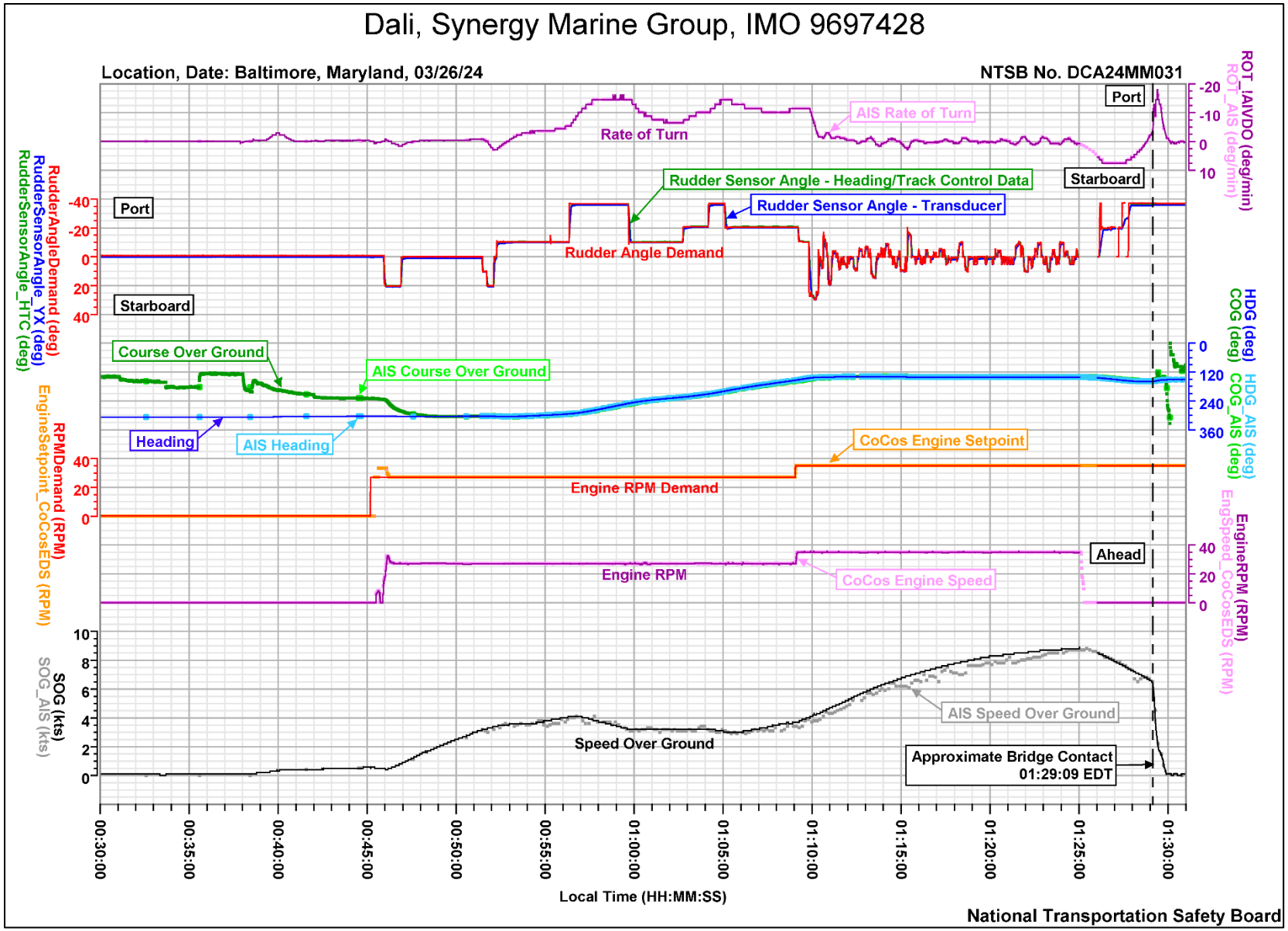

Figure 14. Recorded *Dali* parameters for the time period 00:30:00 to 01:31:00 EDT on March 26, 2024.

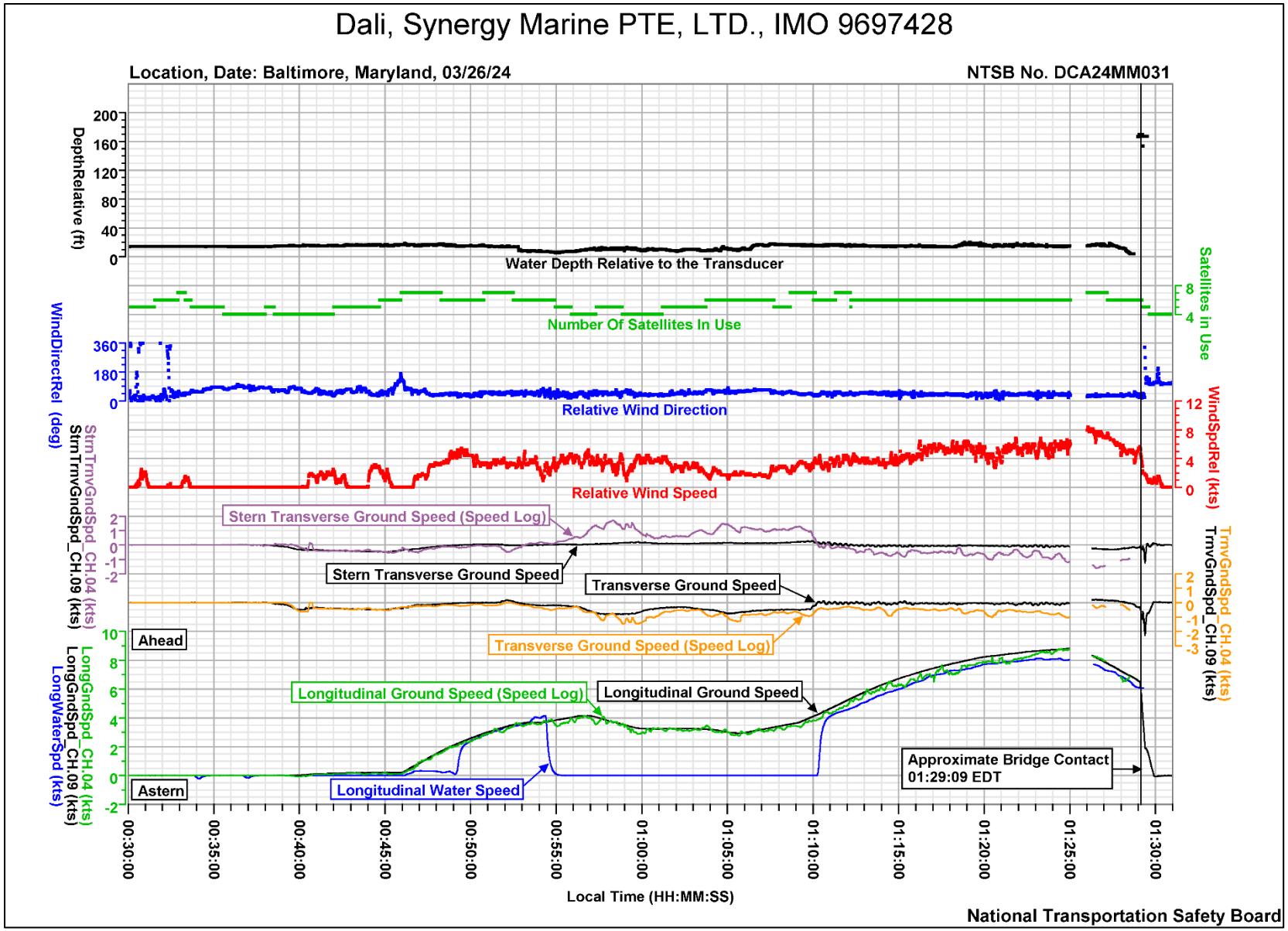

Figure 15. Additional recorded *Dali* parameters for the time period 00:30:00 to 01:31:00 EDT on March 26, 2024.

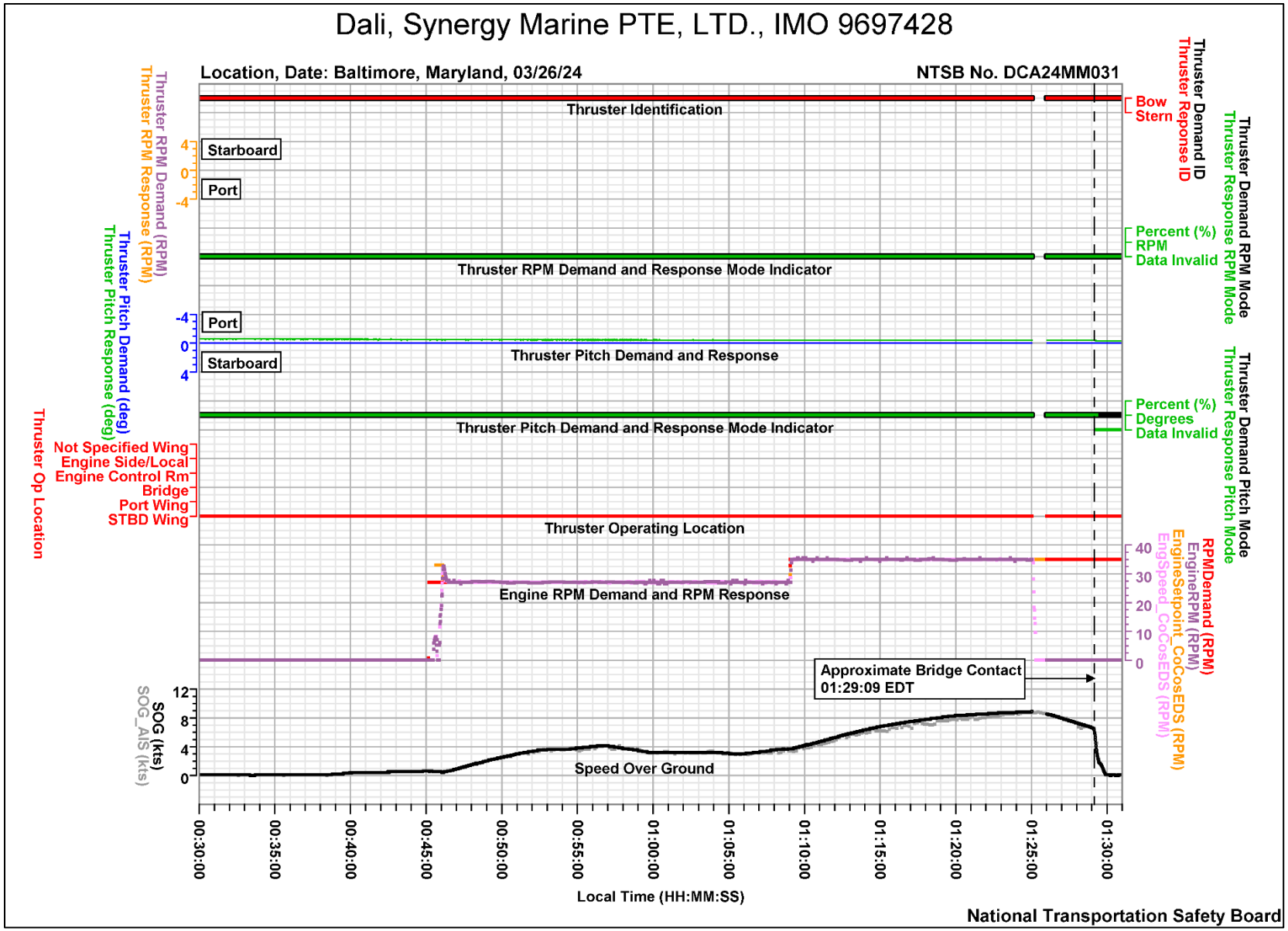

Figure 16. Thruster parameters recorded on the *Dali* for the time period 00:30:00 to 01:31:00 EDT on March 26, 2024.

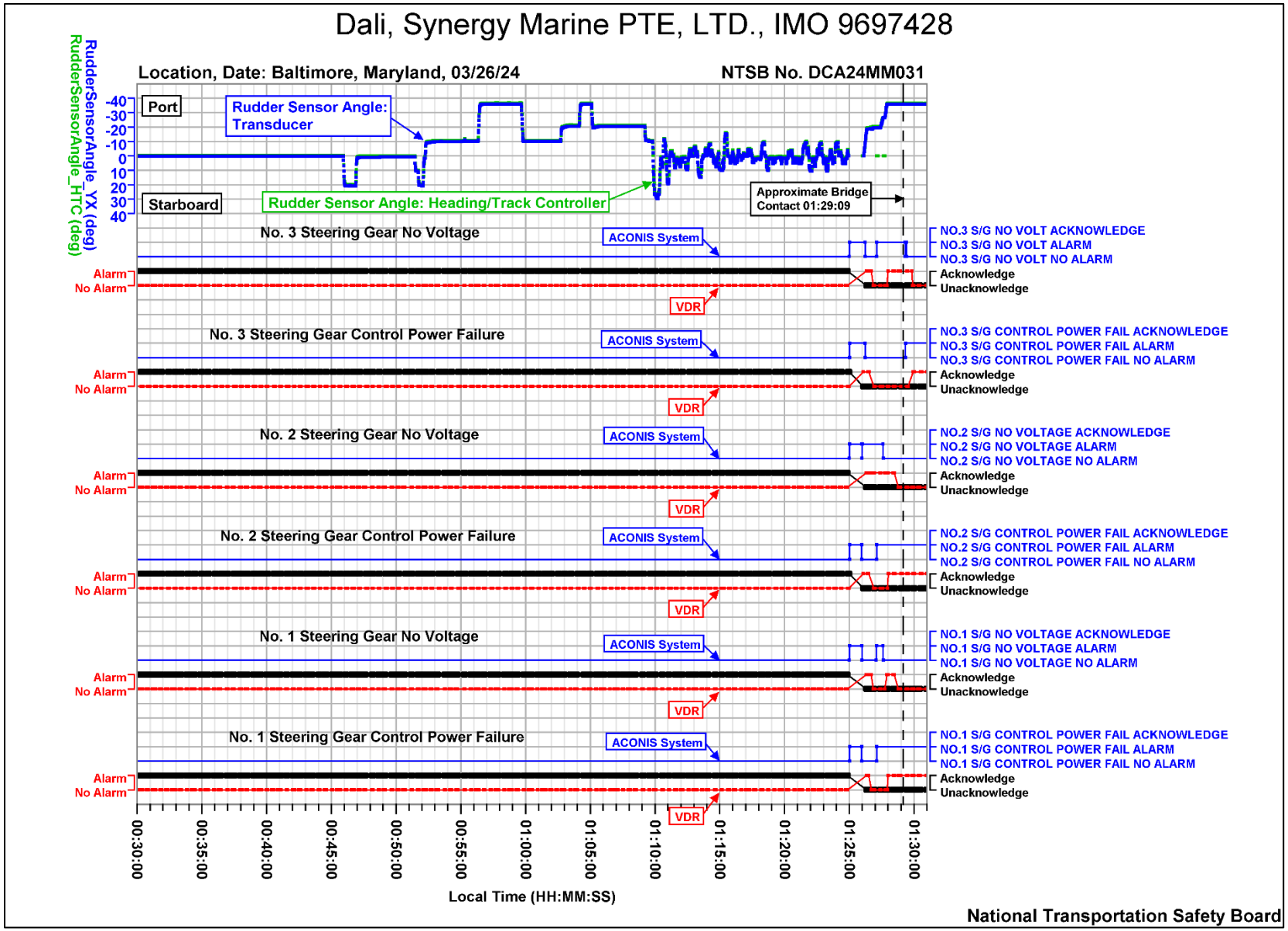

Figure 17. ACONIS steering gear alarms recorded on the *Dali* for the time period 00:30:00 to 01:31:00 EDT on March 26, 2024.

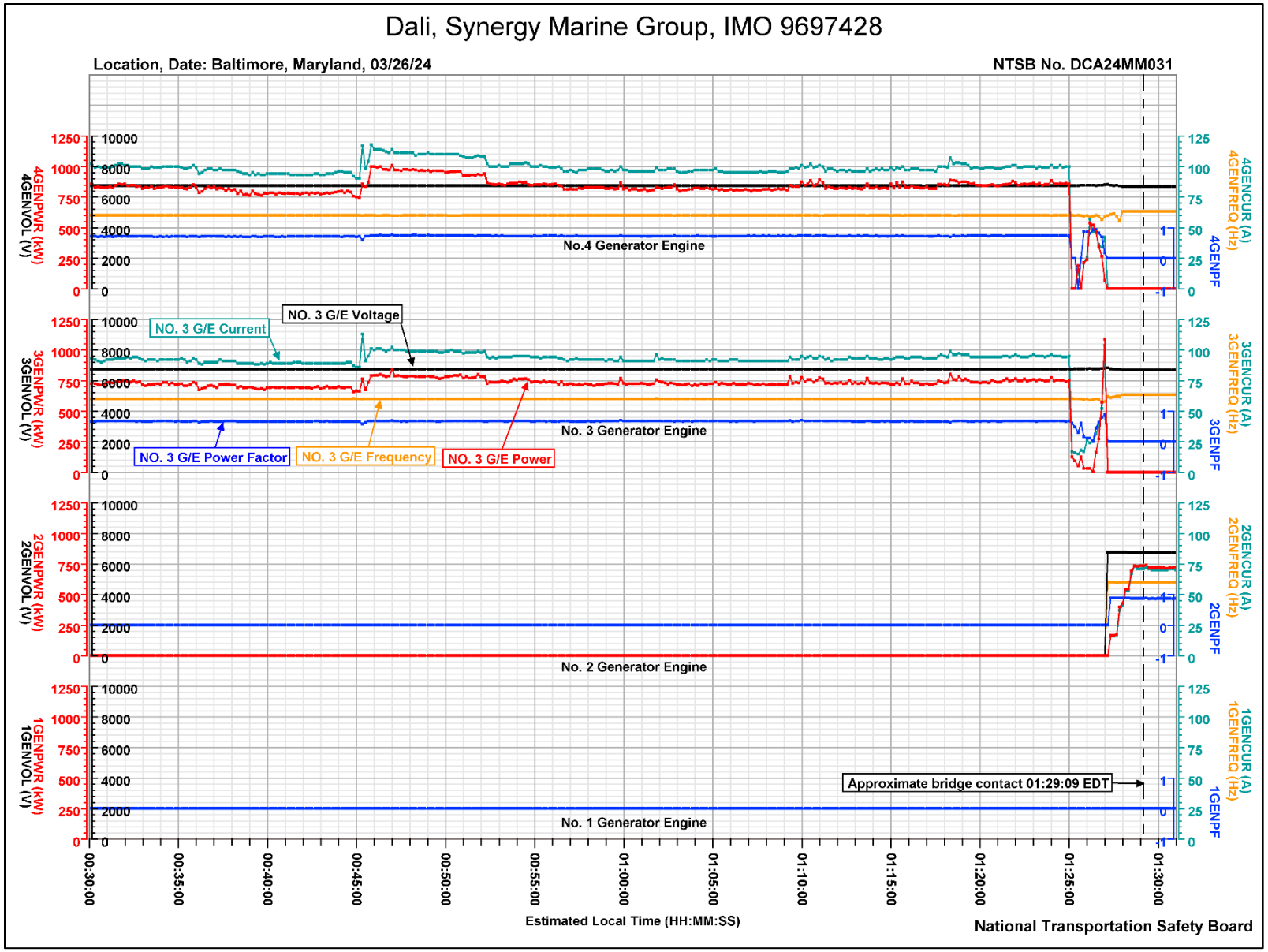

Figure 18. Recorded *Dali* ACONIS generator data for the time period 00:30:00 to 01:31:00 EDT on March 26, 2024.

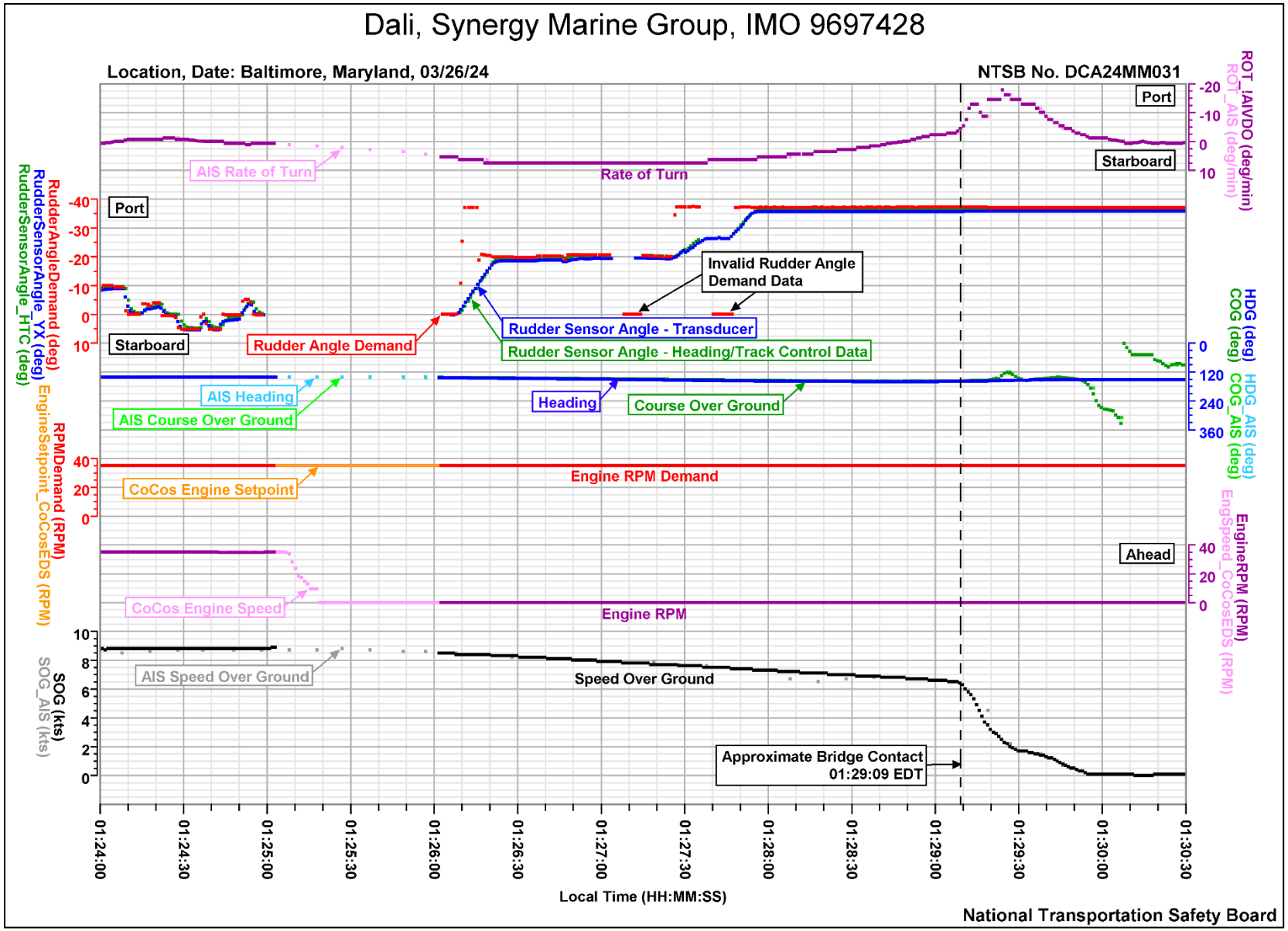

Figure 19. Recorded *Dali* parameters for the time period 01:24:00 to 01:30:30 EDT on March 26, 2024.

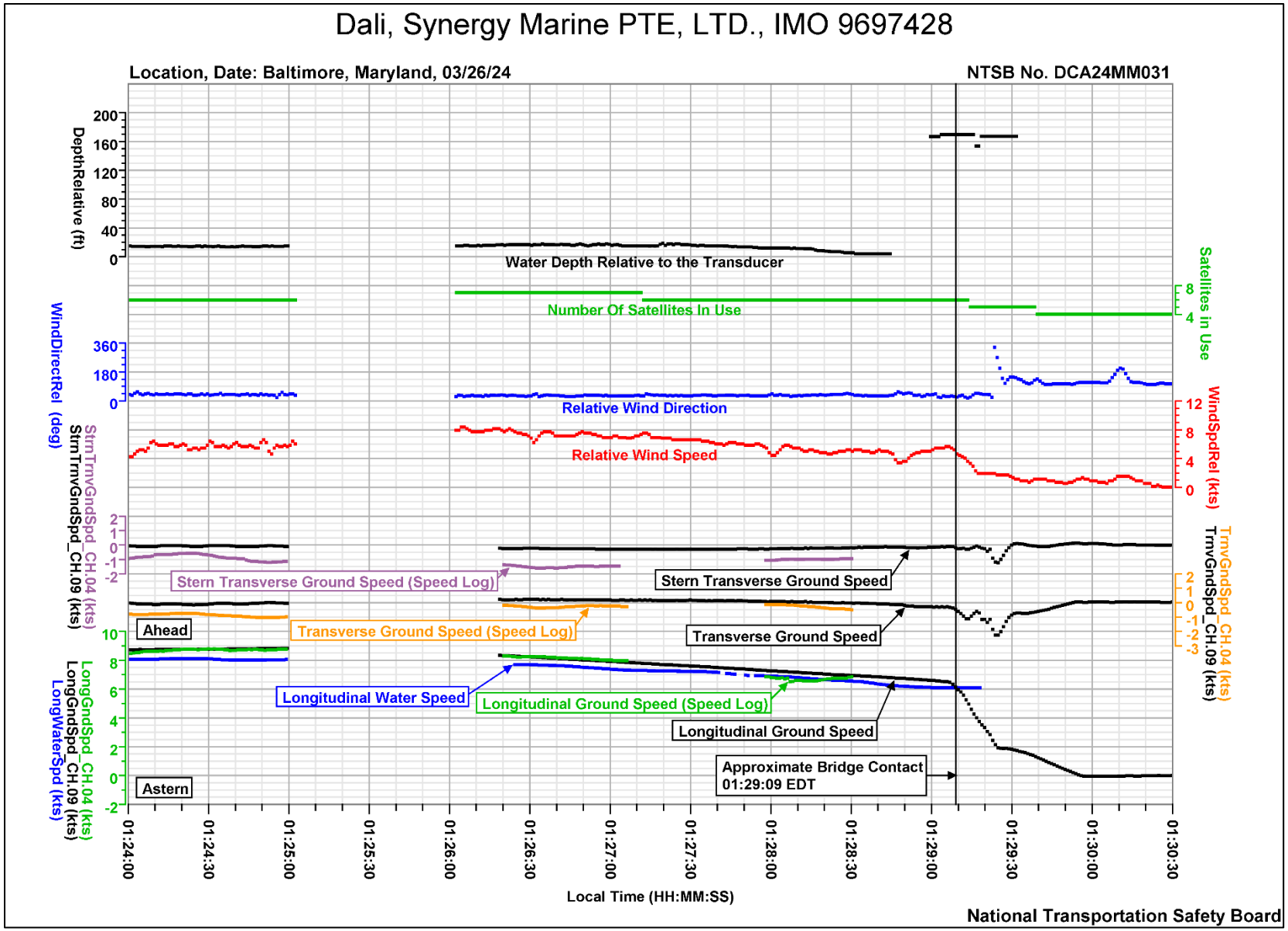

Figure 20. Additional recorded *Dali* parameters for the time period 01:24:00 to 01:30:30 EDT on March 26, 2024.

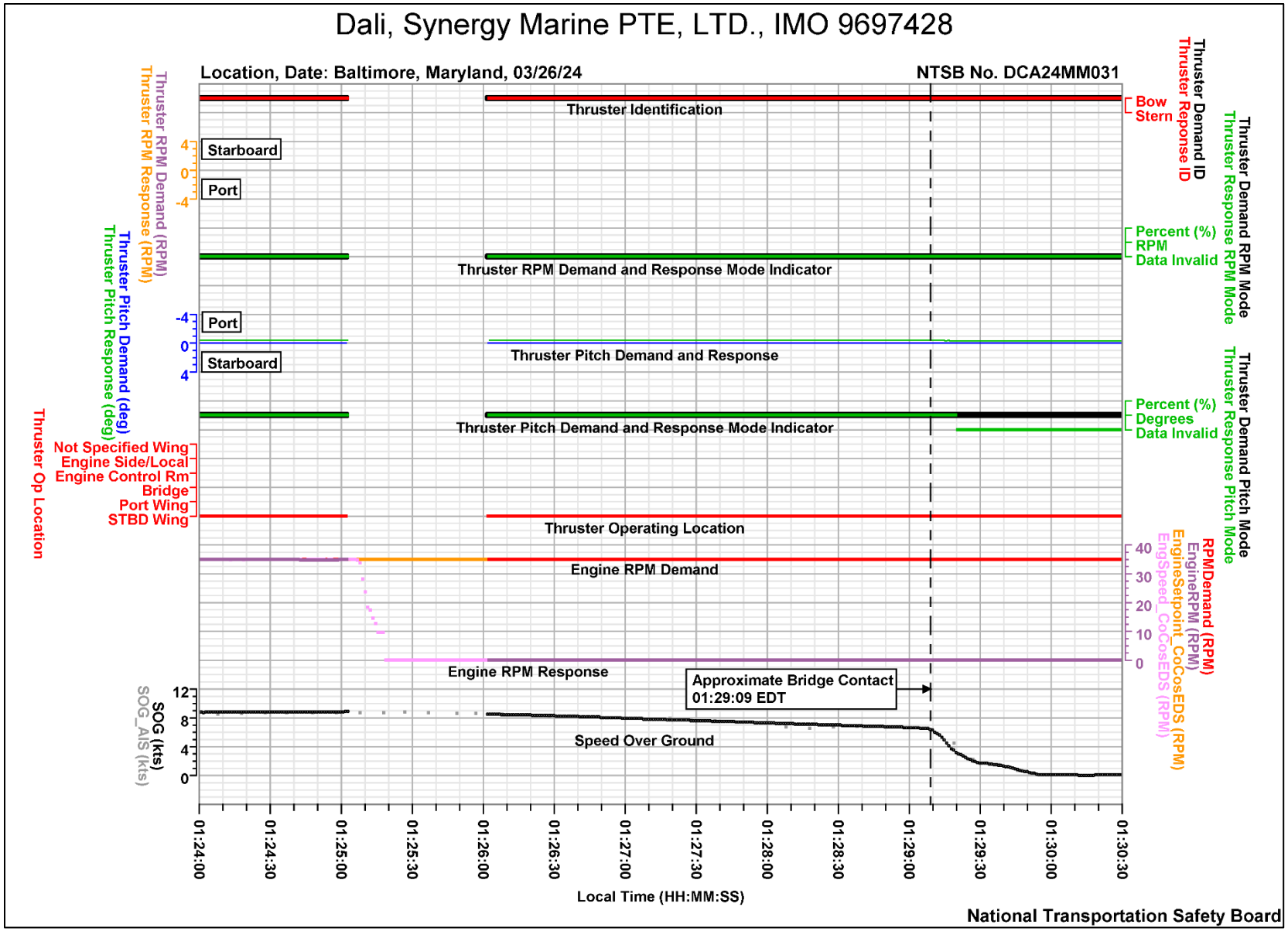

Figure 21. Thruster parameters recorded on the *Dali* for the time period 01:24:00 to 01:30:30 EDT on March 26, 2024.

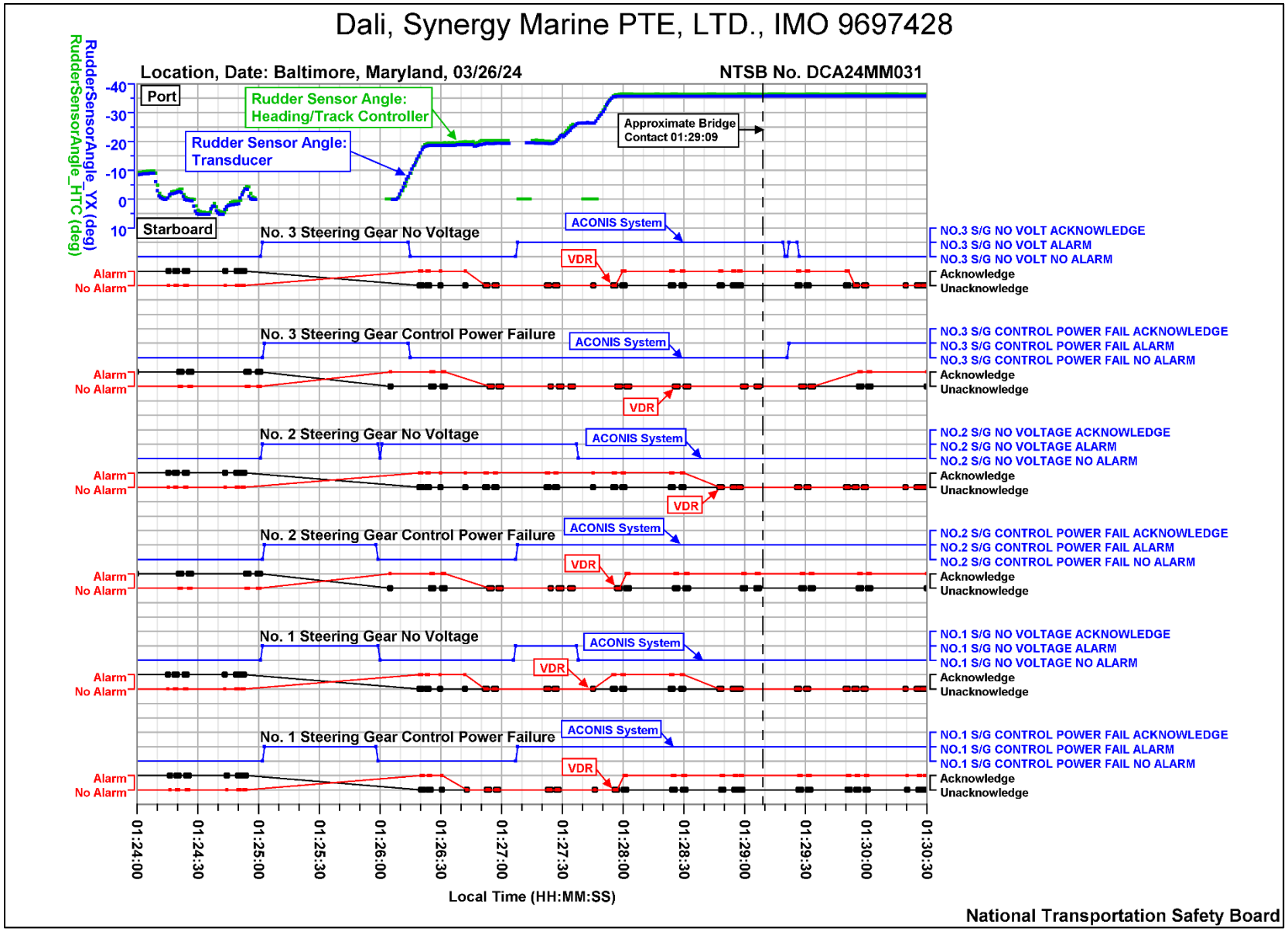

Figure 22. ACONIS steering gear alarms recorded on the *Dali* for the time period 01:24:00 to 01:30:30 EDT on March 26, 2024.

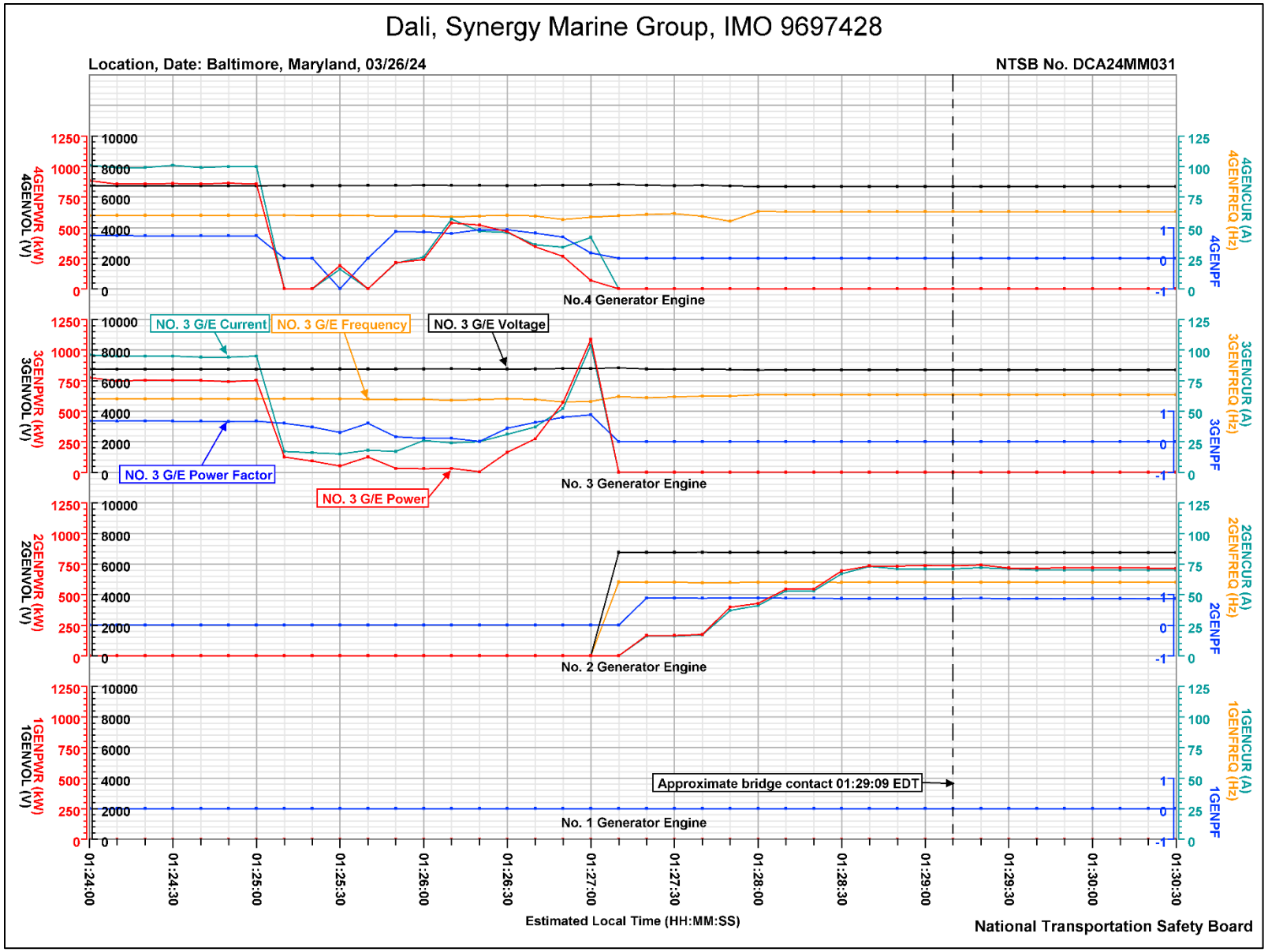

Figure 23. Recorded *Dali* ACONIS generator data for the time period 01:24:00 to 01:30:30 EDT on March 26, 2024.

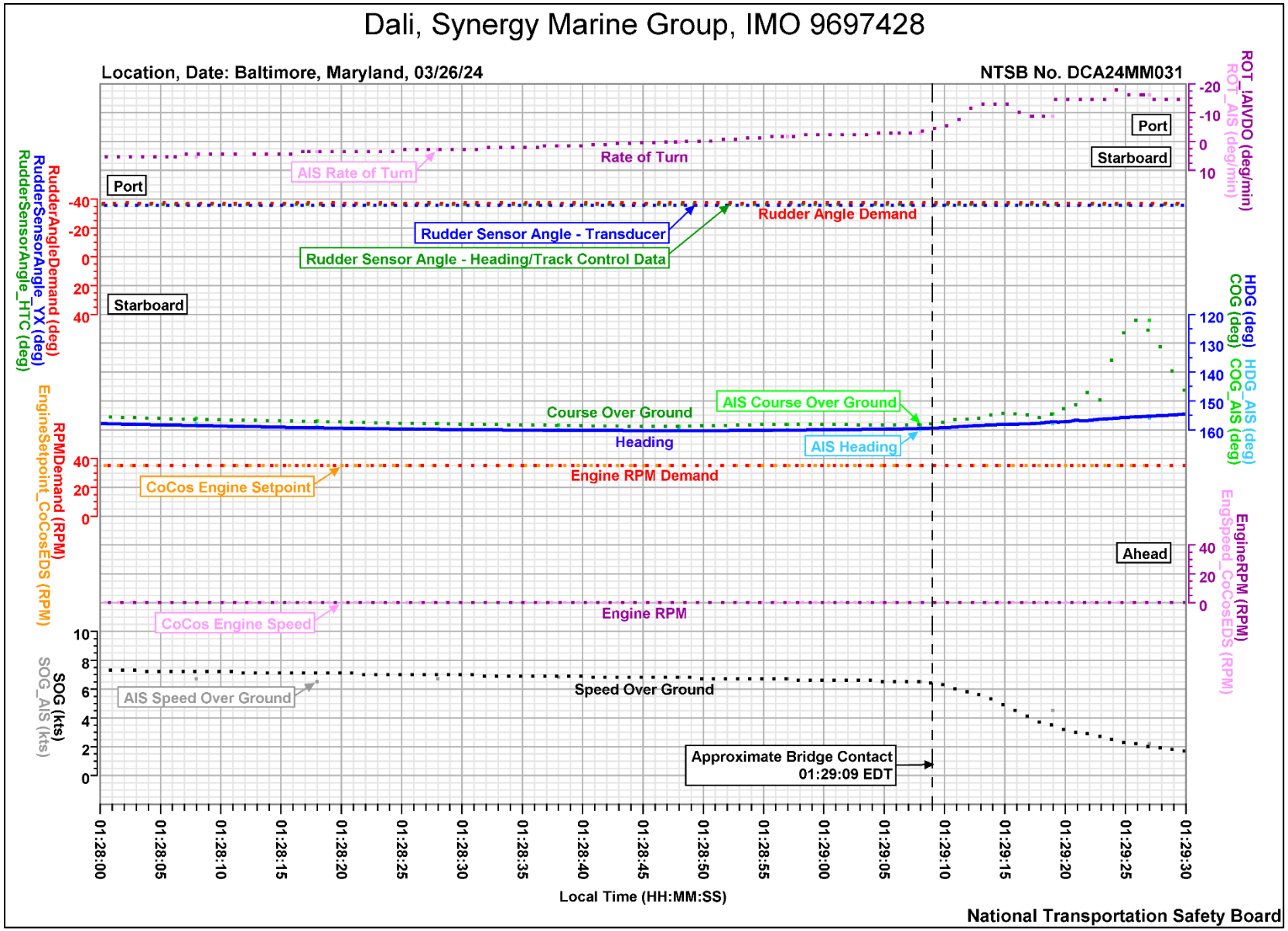

Figure 24. Recorded *Dali* parameters for the time period 01:28:00 to 01:29:30 EDT on March 26, 2024.

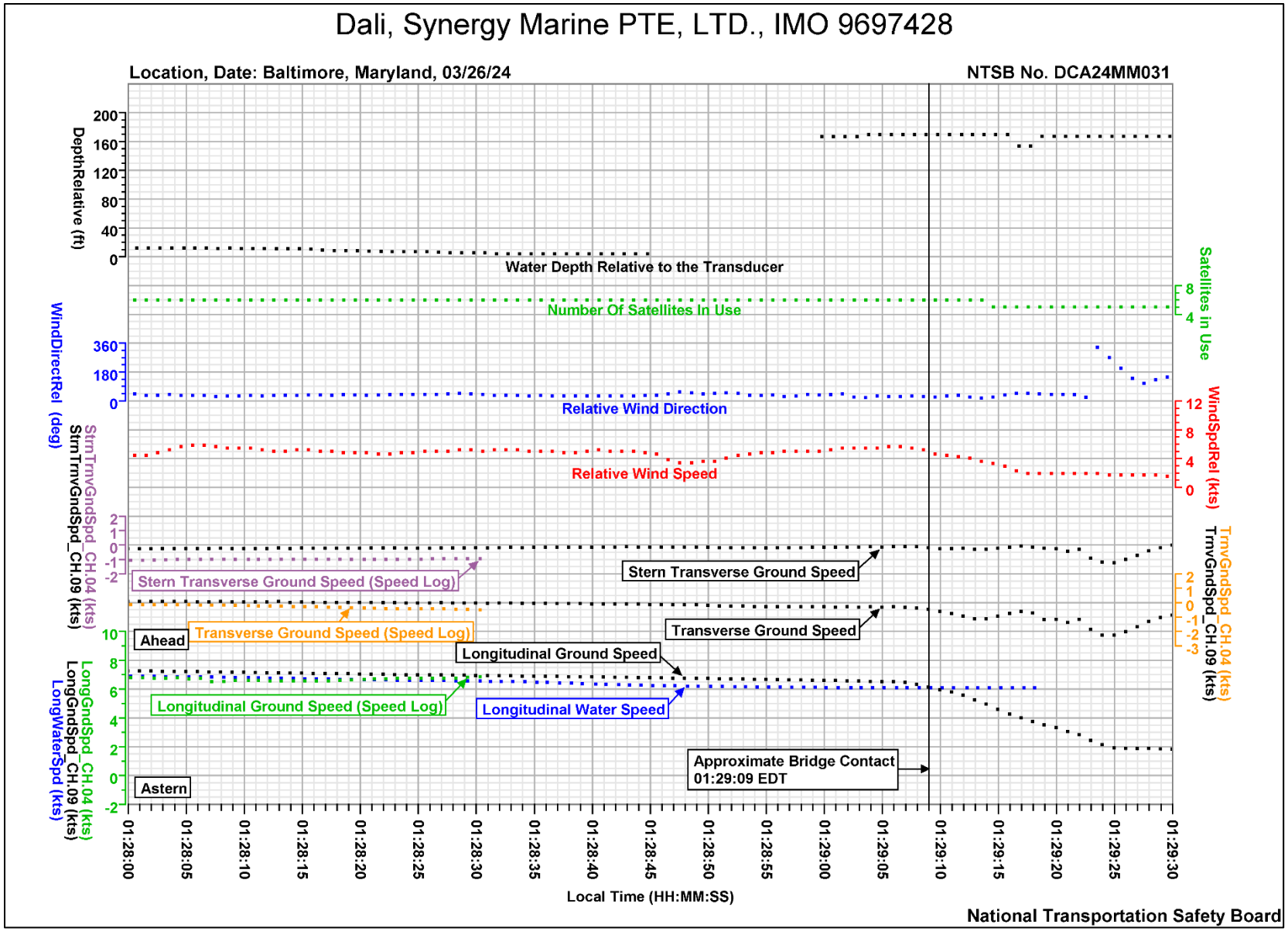

Figure 25. Additional recorded *Dali* parameters for the time period 01:28:00 to 01:29:30 EDT on March 26, 2024.

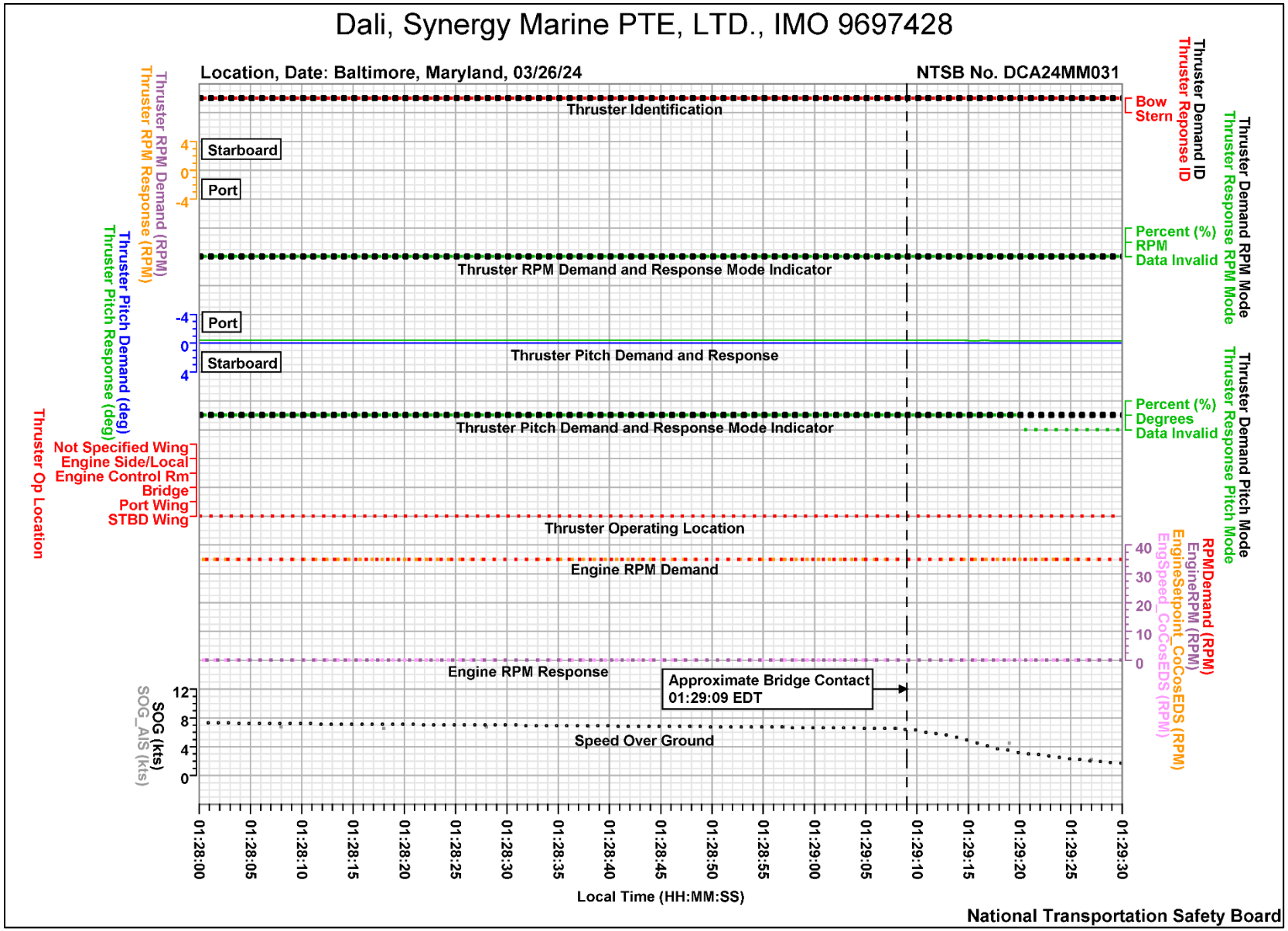

Figure 26. Thruster parameters recorded on the *Dali* for the time period 01:28:00 to 01:29:30 EDT on March 26, 2024.

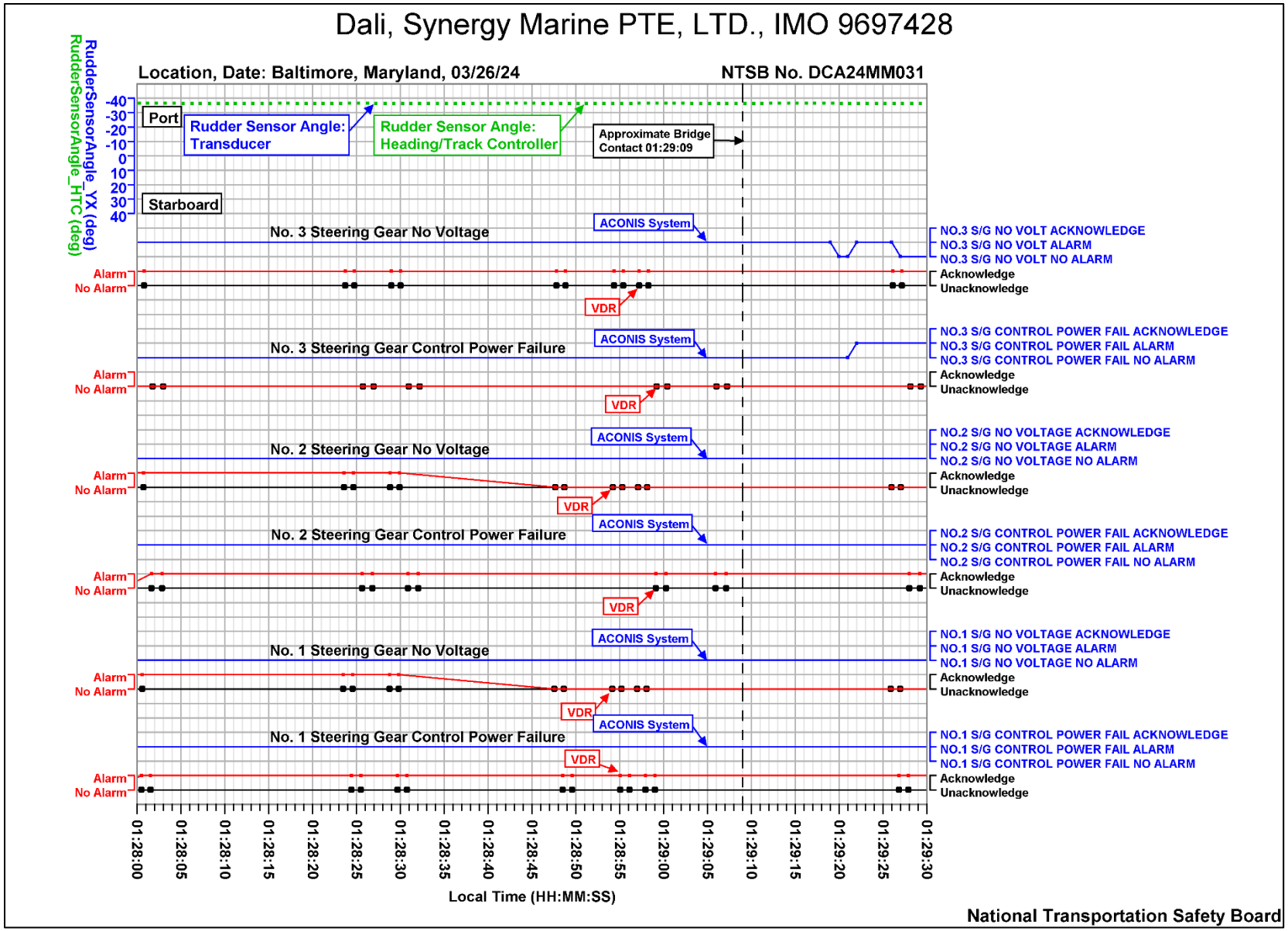

Figure 27. ACONIS steering gear alarms recorded on the *Dali* for the time period 01:28:00 to 01:29:30 EDT on March 26, 2024.

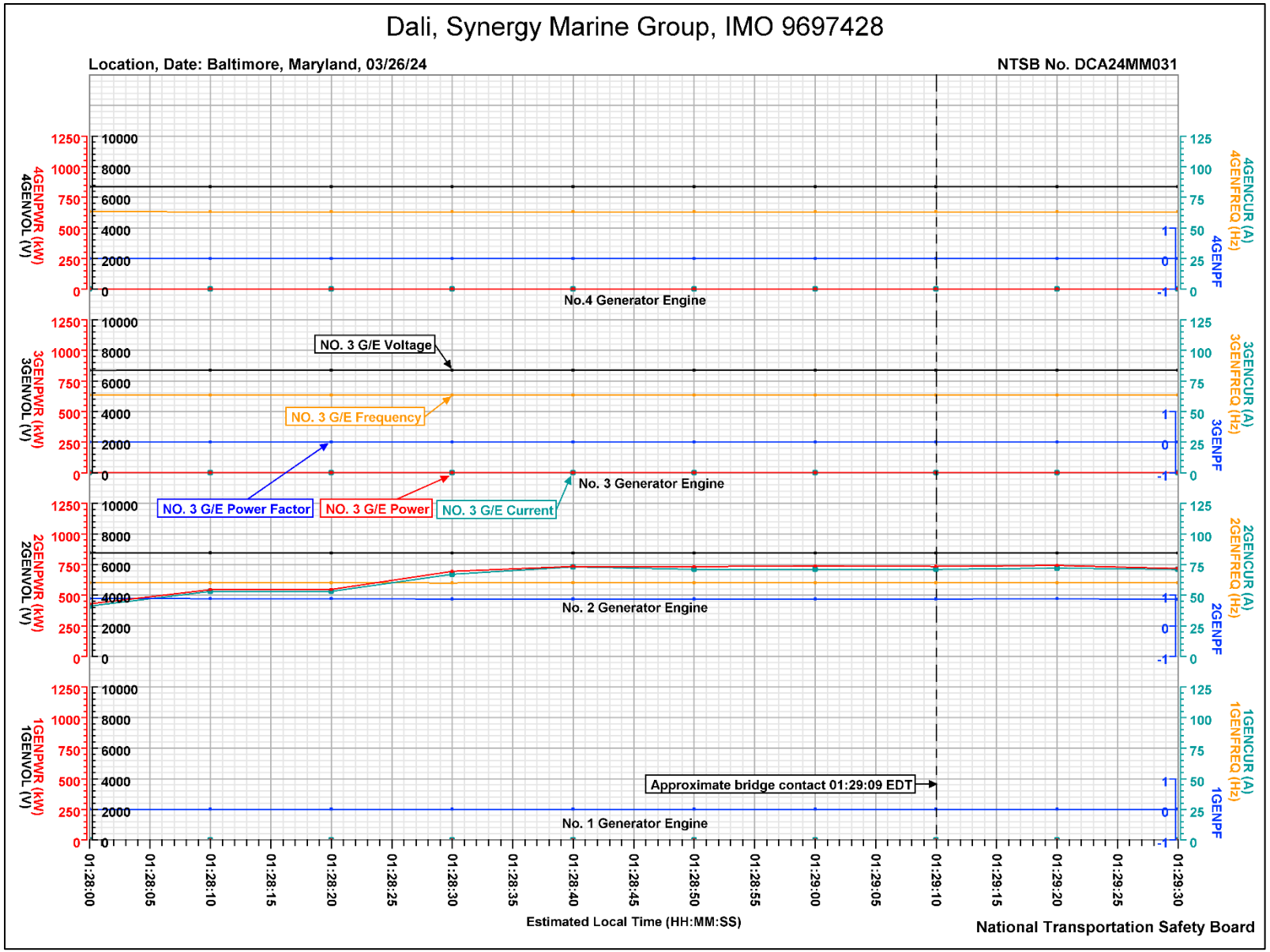

Figure 28. Recorded *Dali* ACONIS generator data for the time period 01:28:00 to 01:29:30 EDT on March 26, 2024.

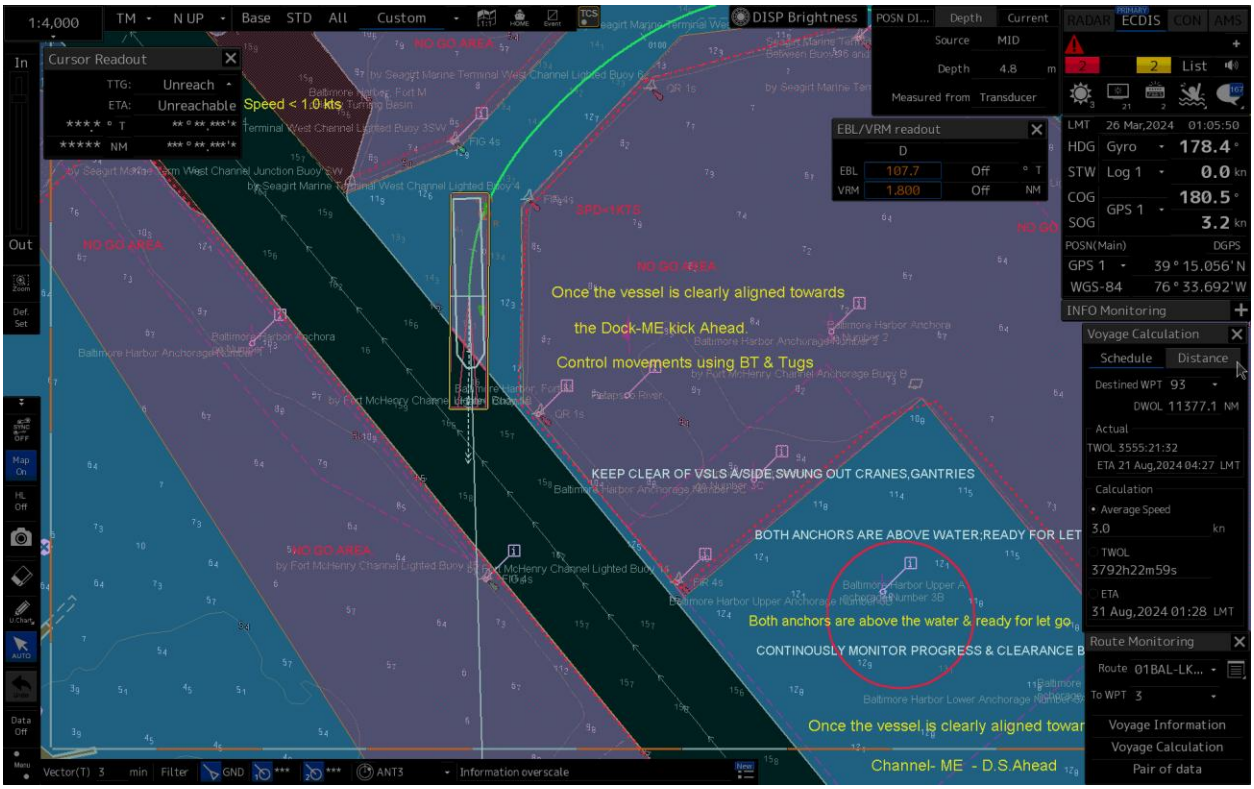

Figure 29. ECDIS display at approximately 01:06:51 EDT. Note that all of the ECDIS and Radar screenshots contain the uncorrected timestamp.

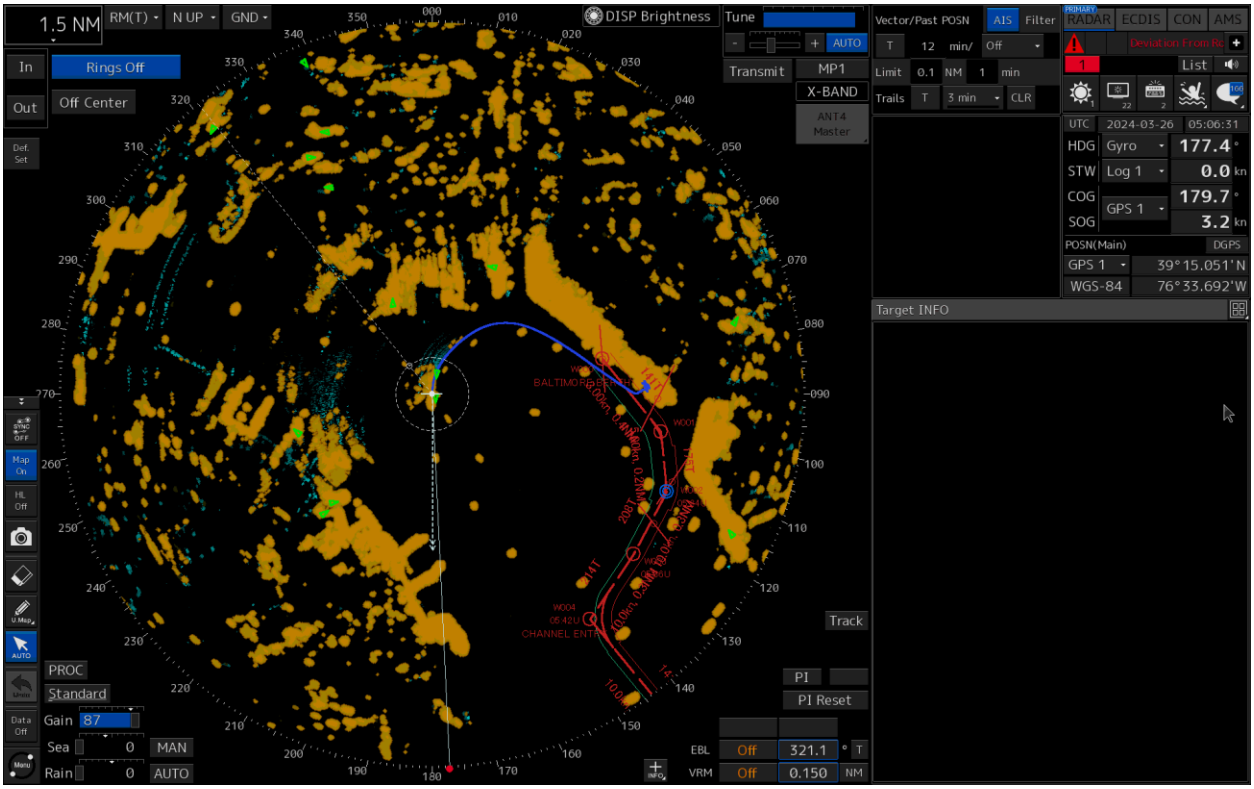

Figure 30. X-Band radar display at approximately 01:06:56 EDT.

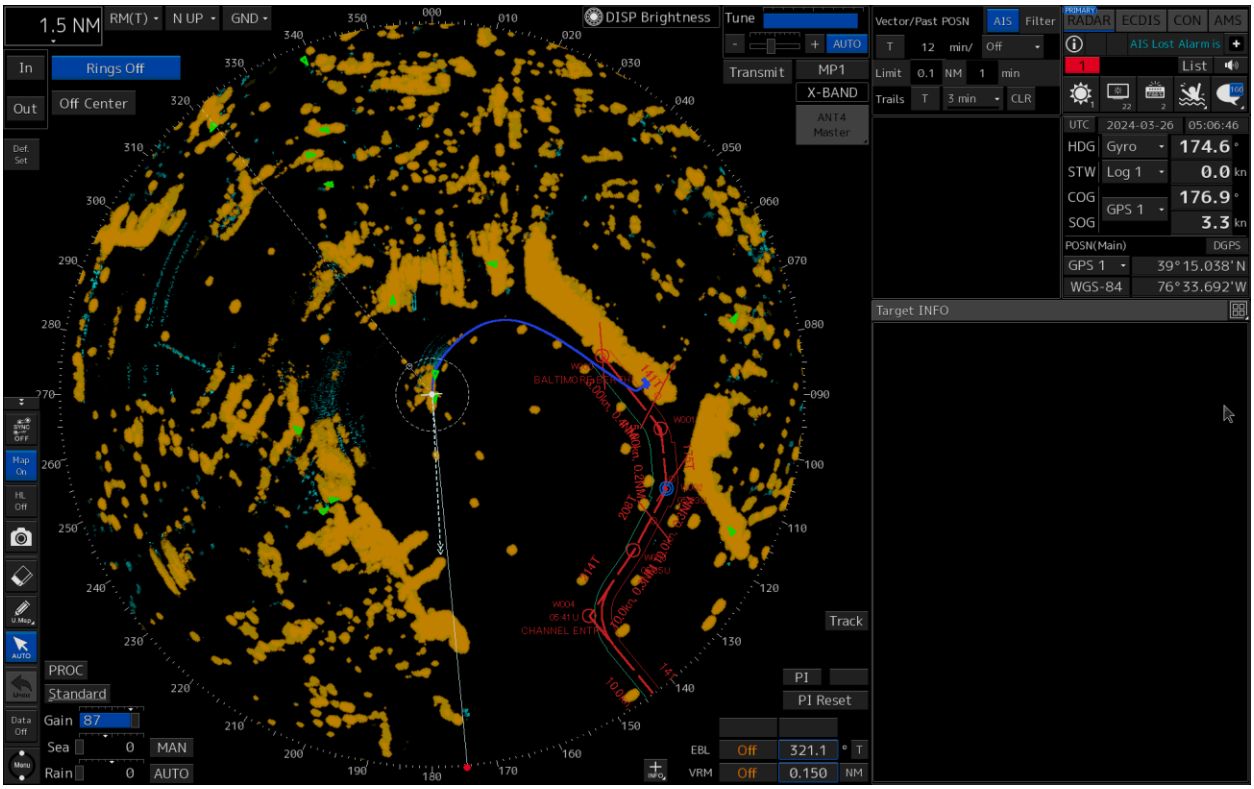

Figure 31. X-Band radar display at approximately 01:07:11 EDT.

Figure 32. ECDIS display at approximately 01:07:16 EDT.

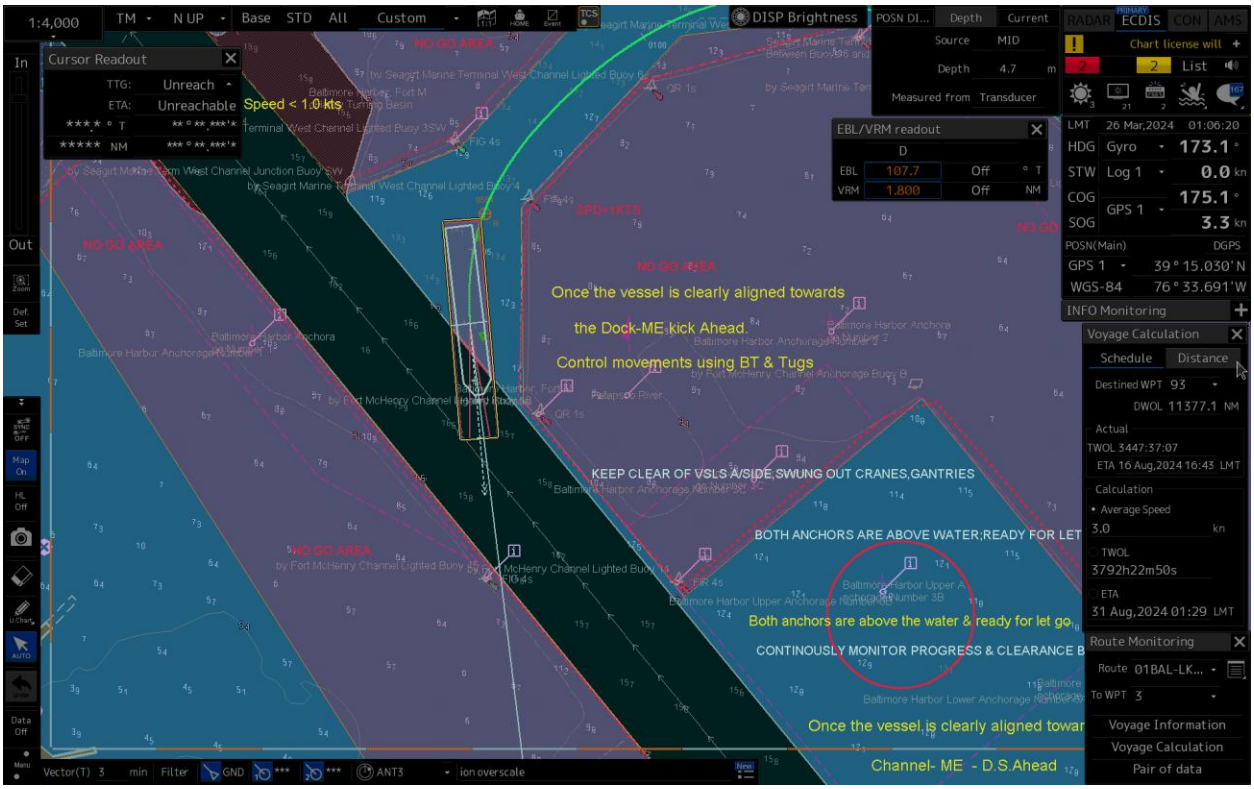

Figure 33. ECDIS display at approximately 01:07:21 EDT.

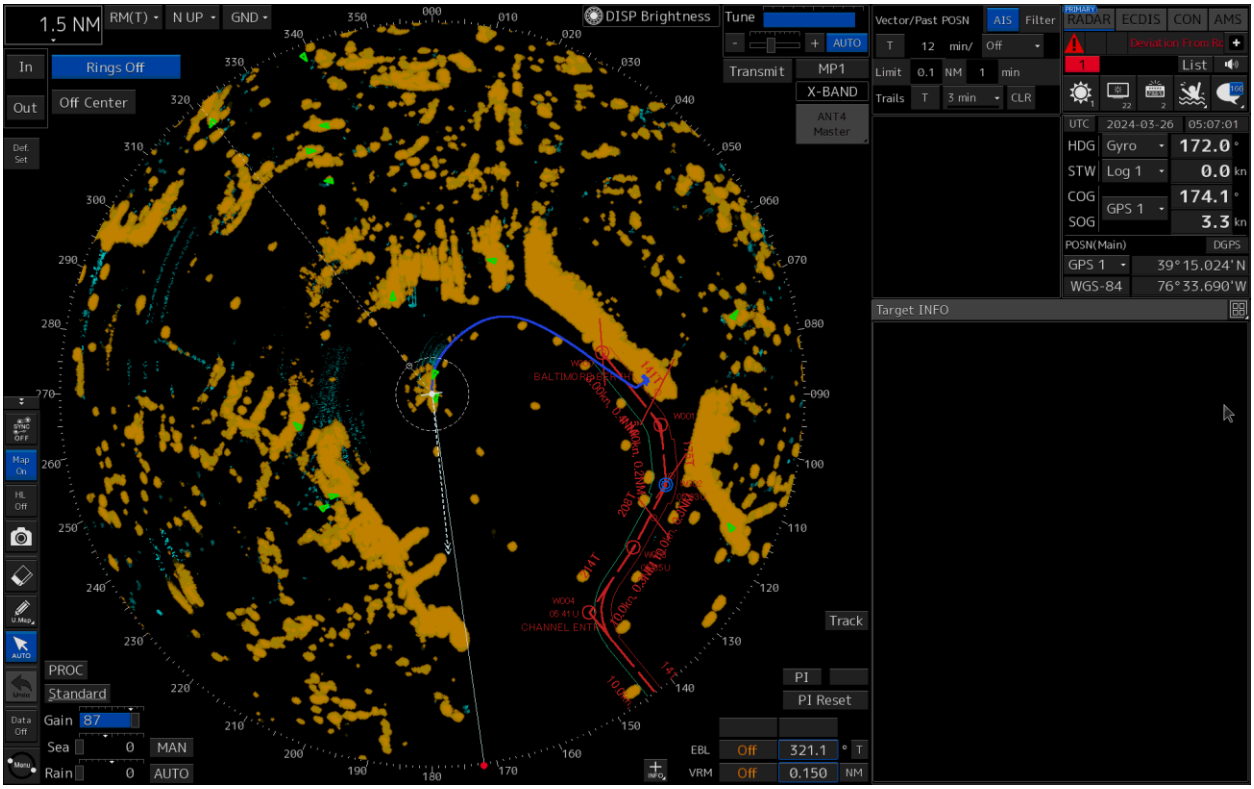

Figure 34. X-Band radar display at approximately 01:07:26 EDT.

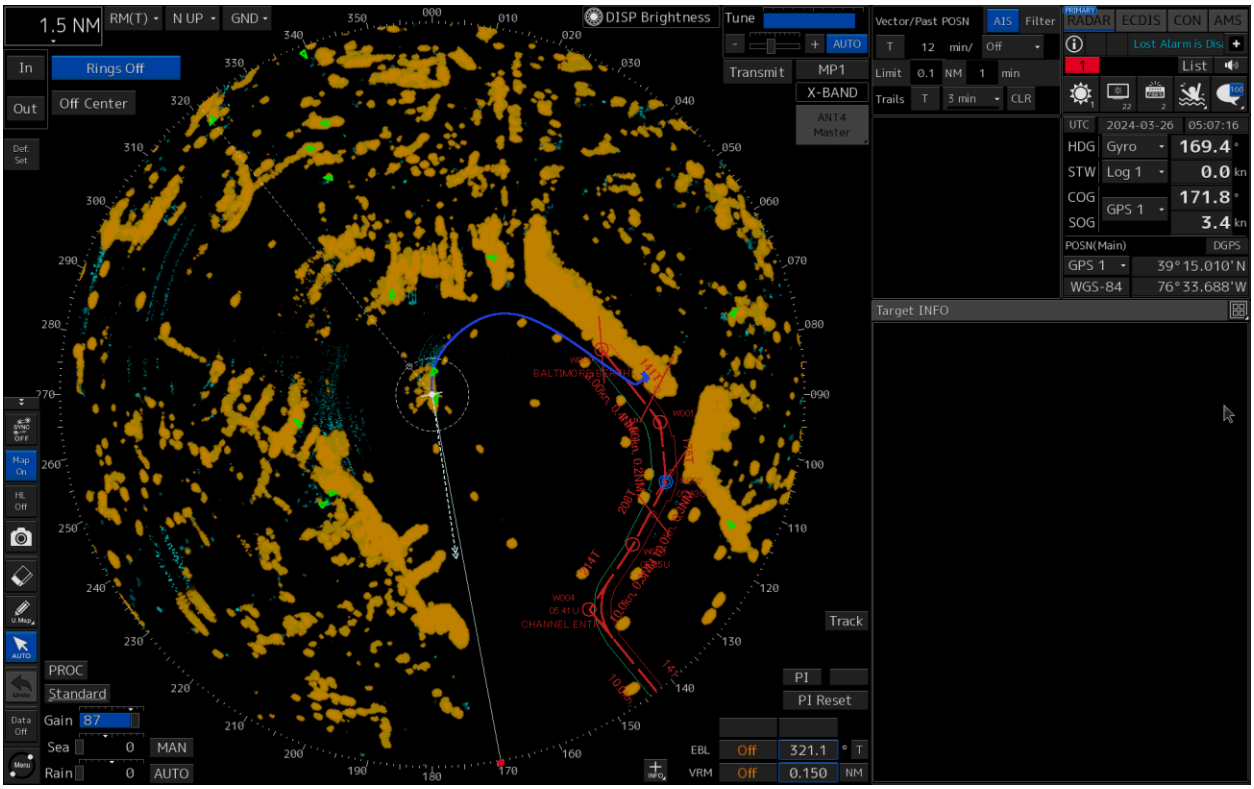

Figure 35. X-Band radar display at approximately 01:07:41 EDT.

Figure 36. ECDIS display at approximately 01:07:46 EDT.

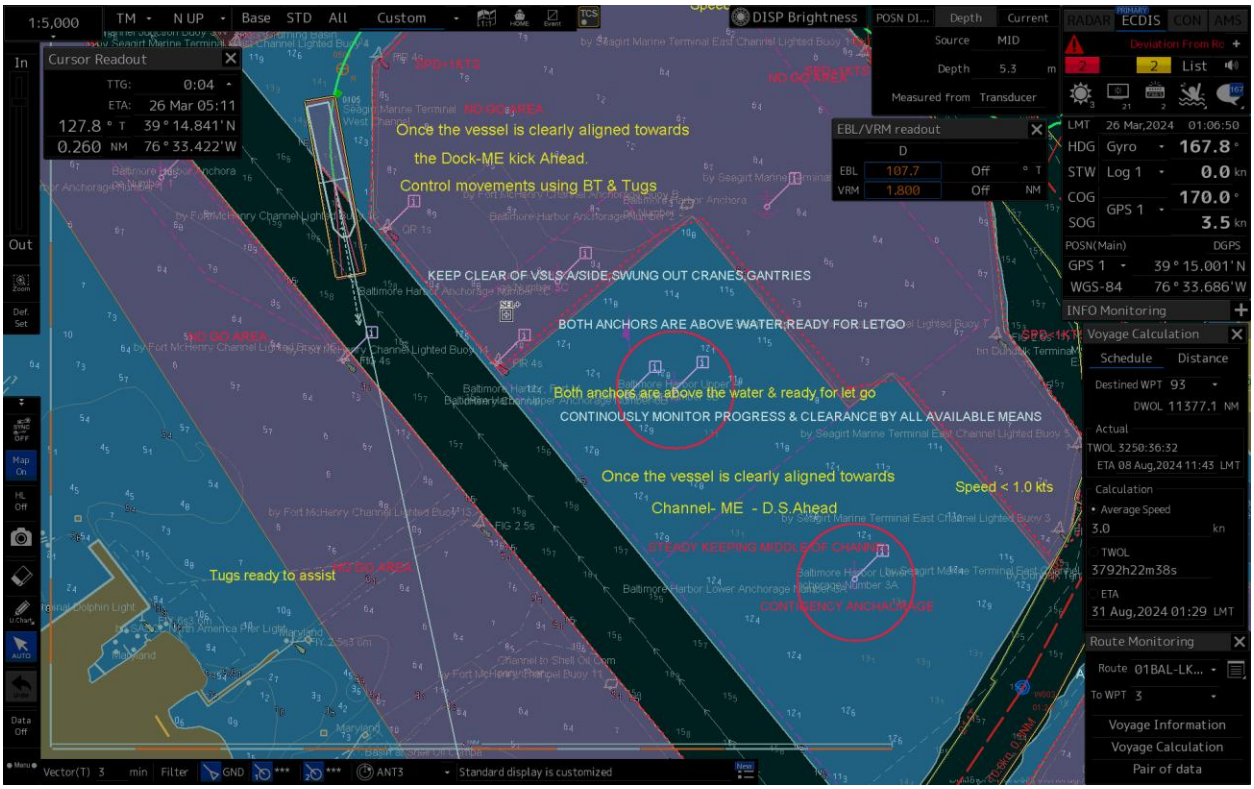

Figure 37. ECDIS display at approximately 01:07:51 EDT.

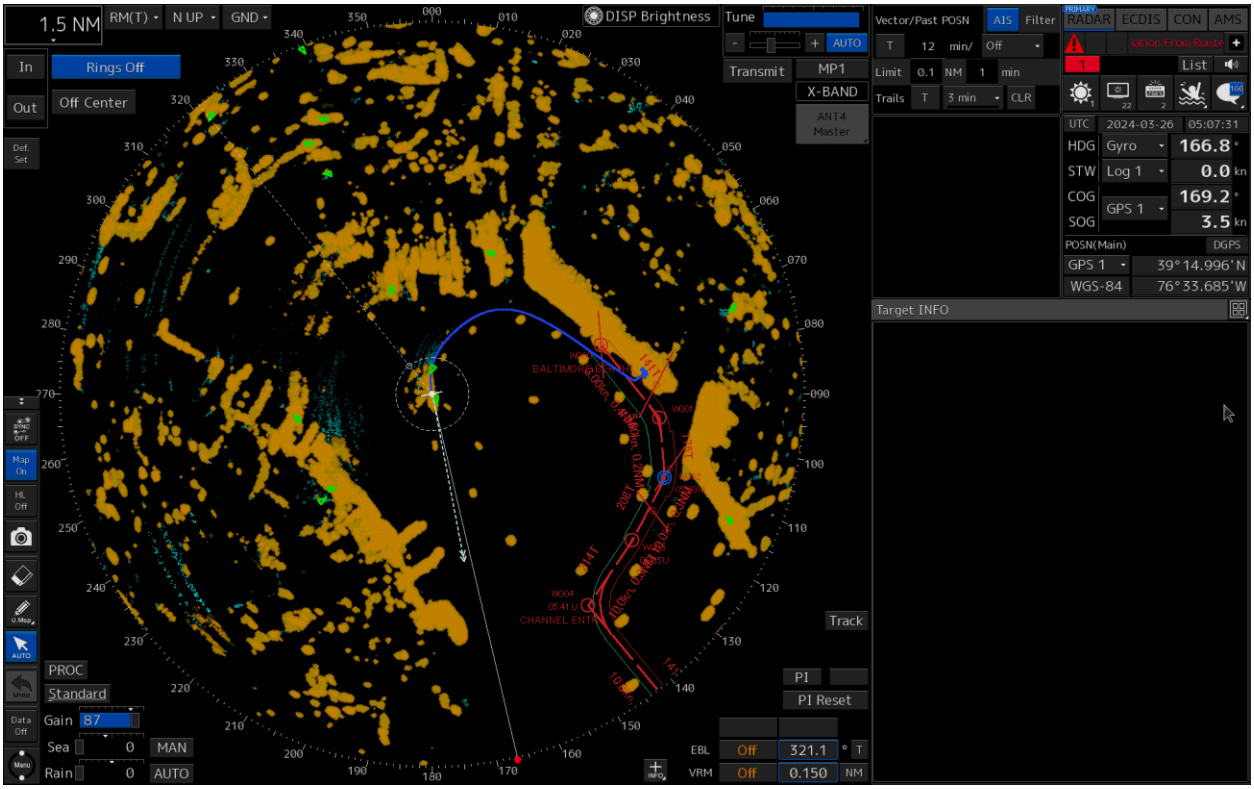

Figure 38. X-Band radar display at approximately 01:07:56 EDT.

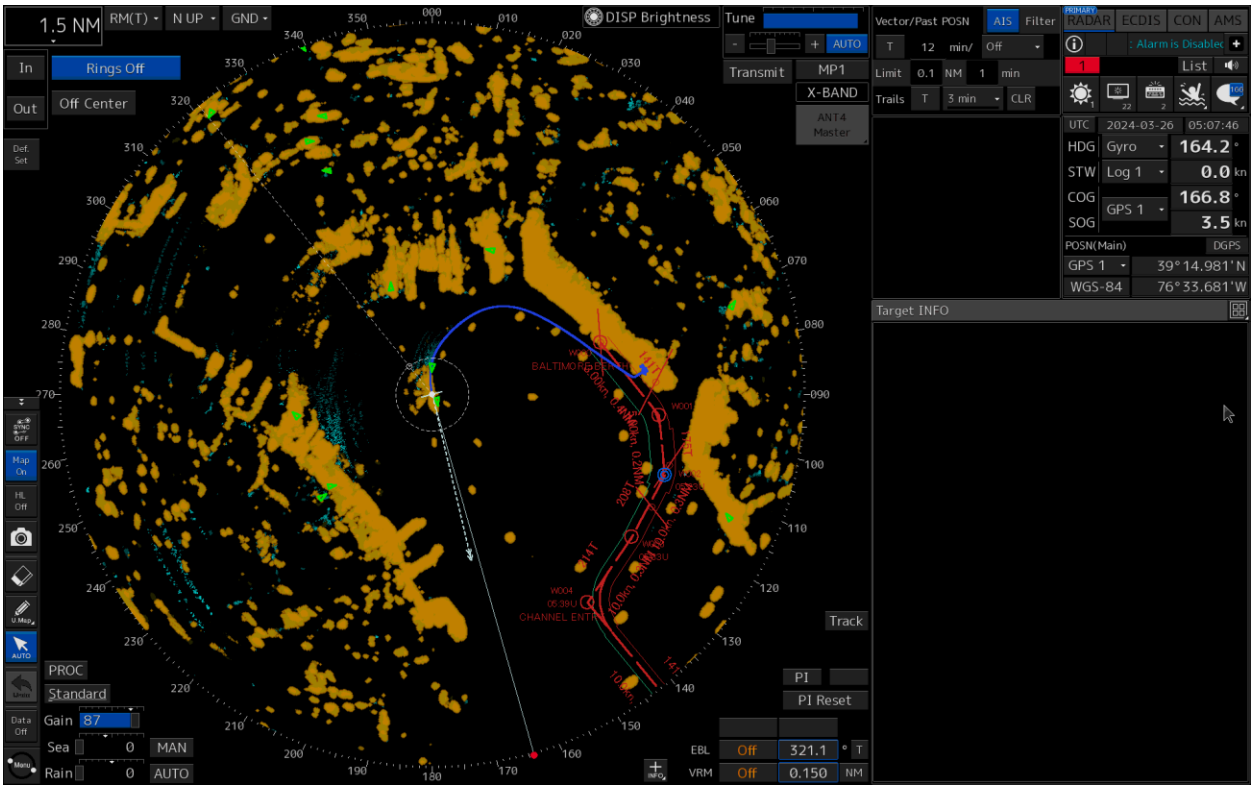

Figure 39. X-Band radar display at approximately 01:08:11 EDT.

Figure 40. ECDIS display at approximately 01:08:16 EDT.

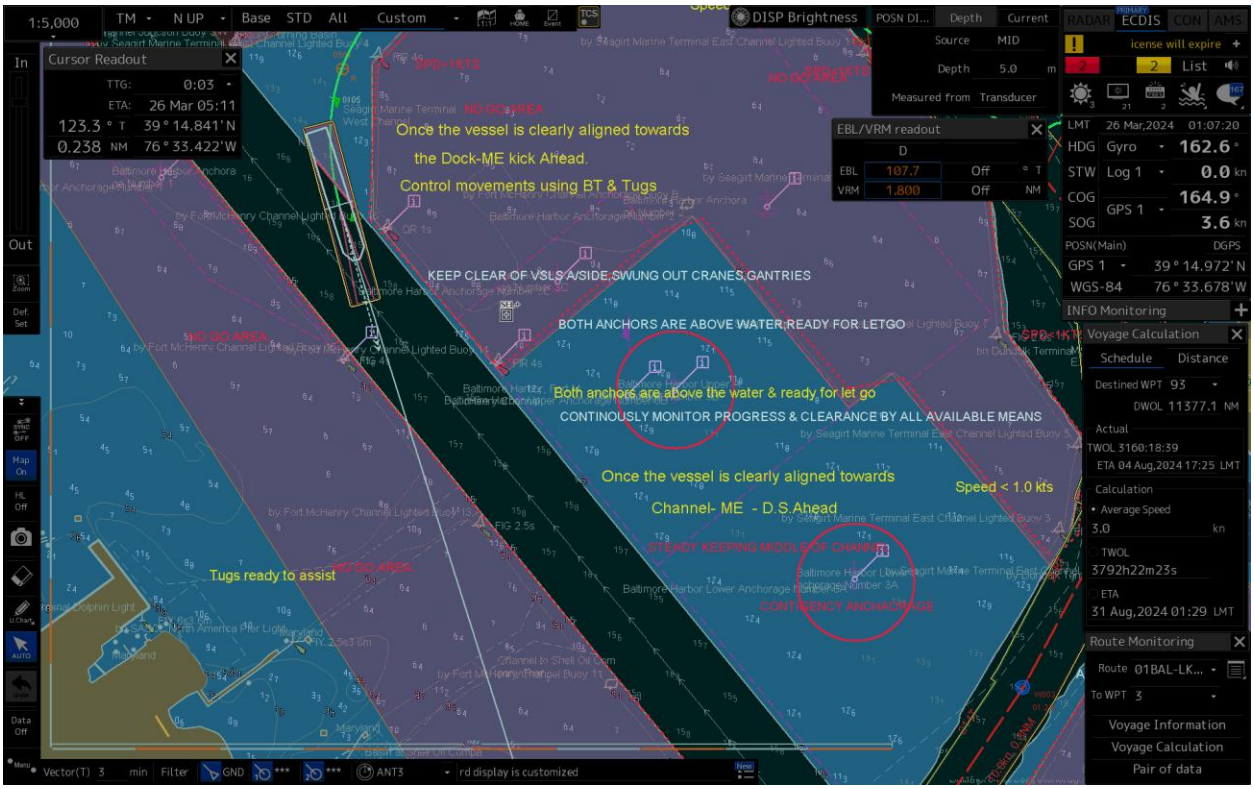

Figure 41. ECDIS display at approximately 01:08:21 EDT.

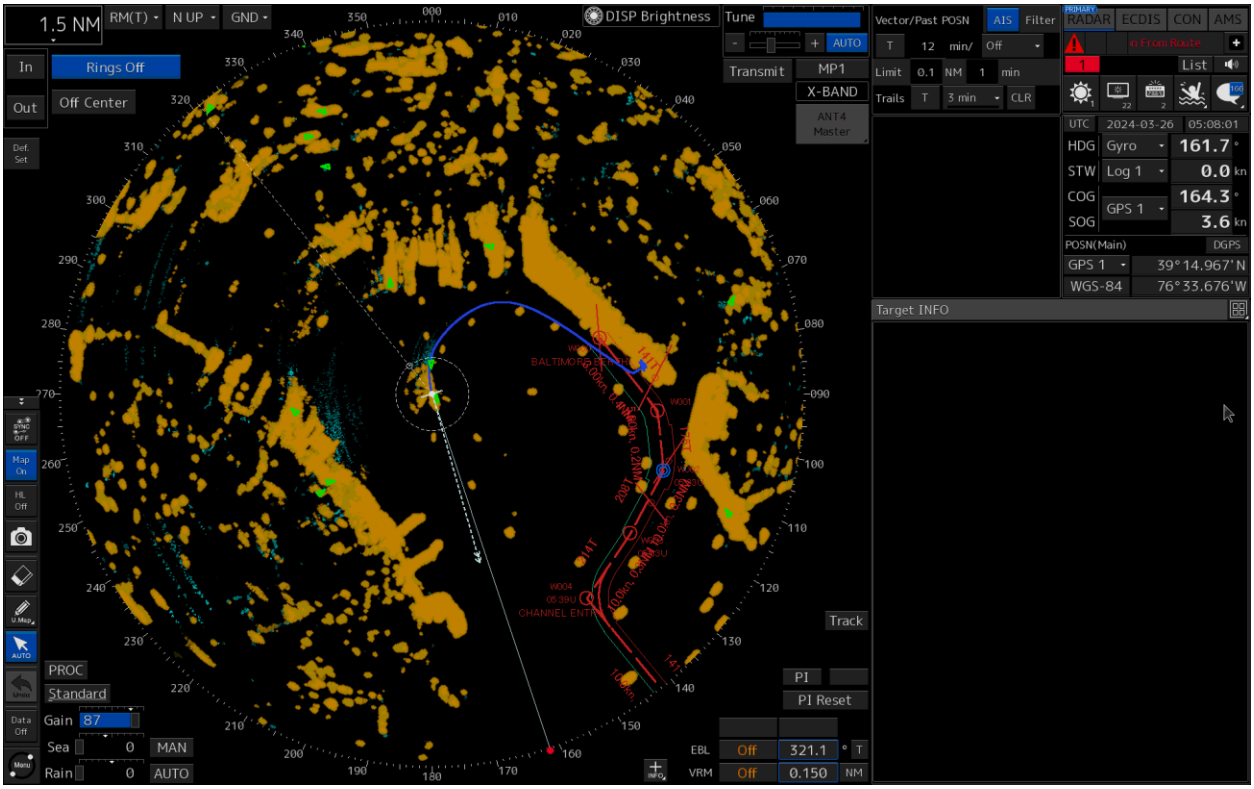

Figure 42. X-Band radar display at approximately 01:08:26 EDT.

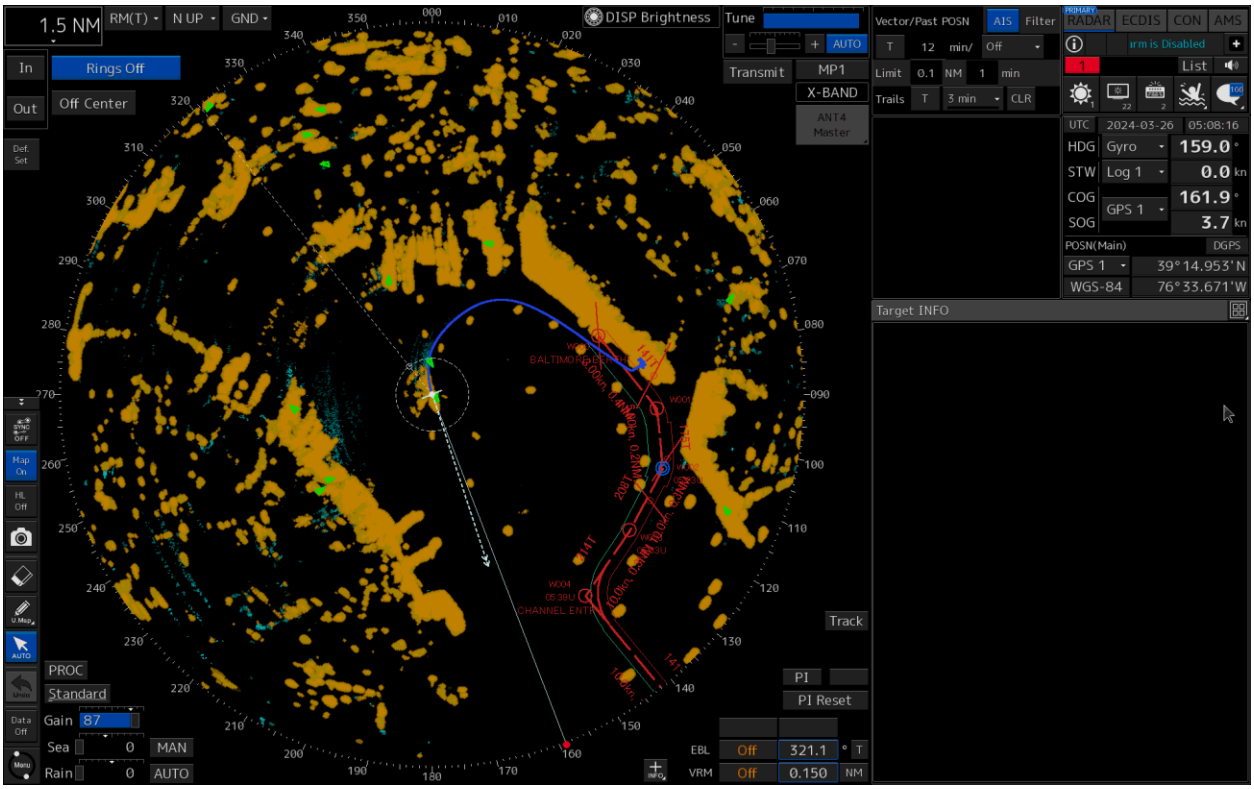

Figure 43. X-Band radar display at approximately 01:08:41 EDT.

Figure 44. ECDIS display at approximately 01:08:46 EDT.

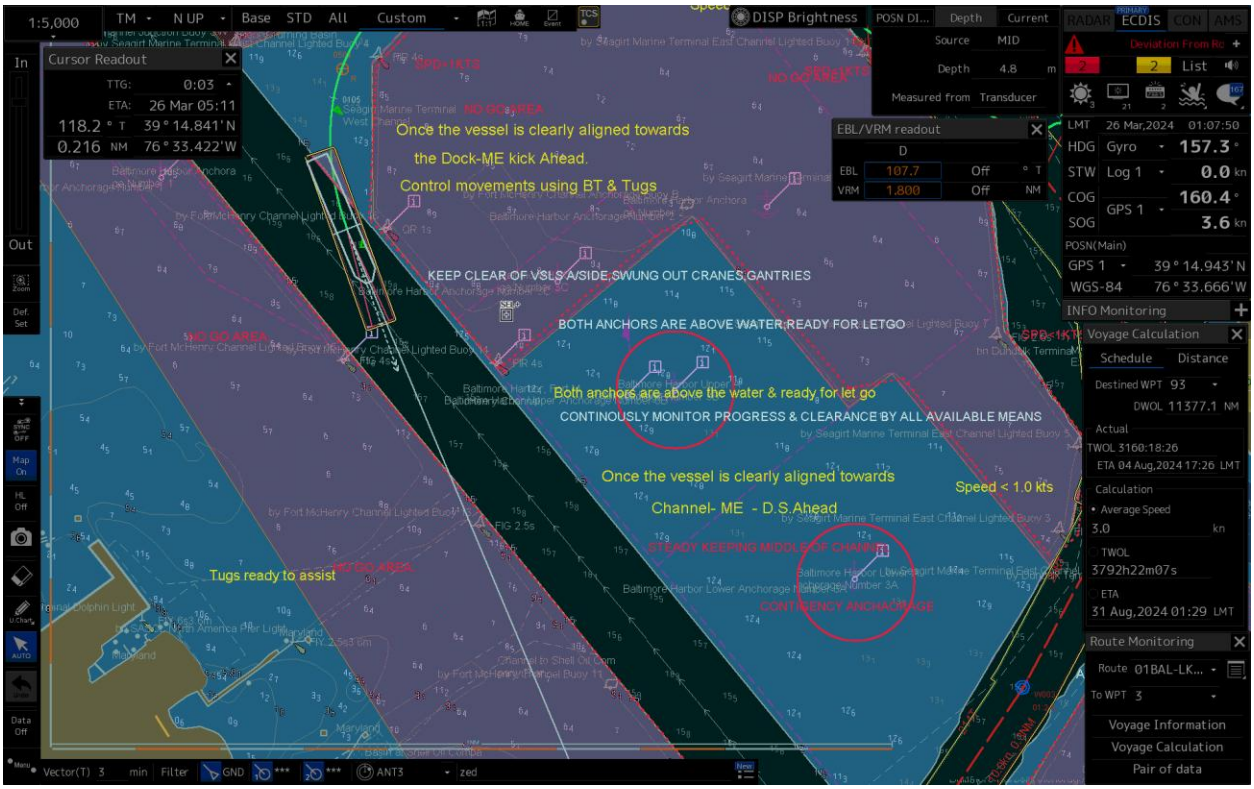

Figure 45. ECDIS display at approximately 01:08:51 EDT.

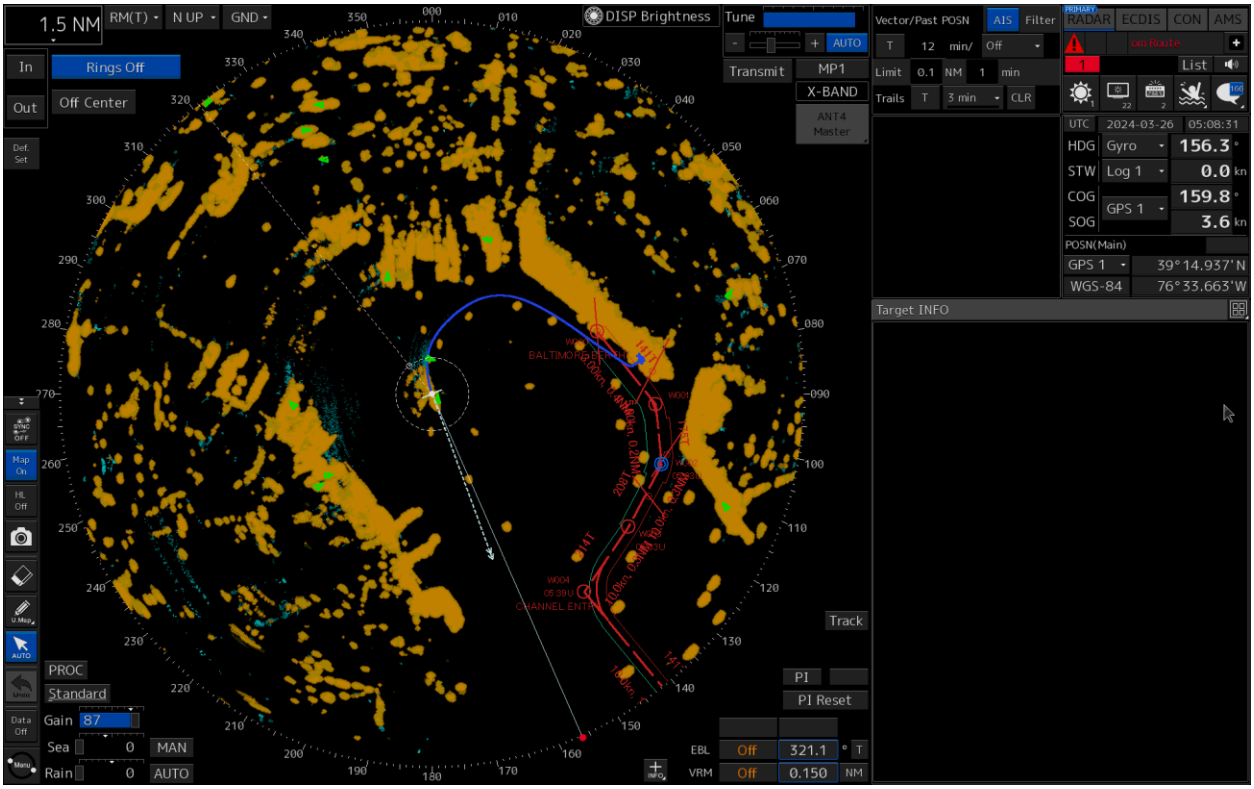

Figure 46. X-Band radar display at approximately 01:08:56 EDT.

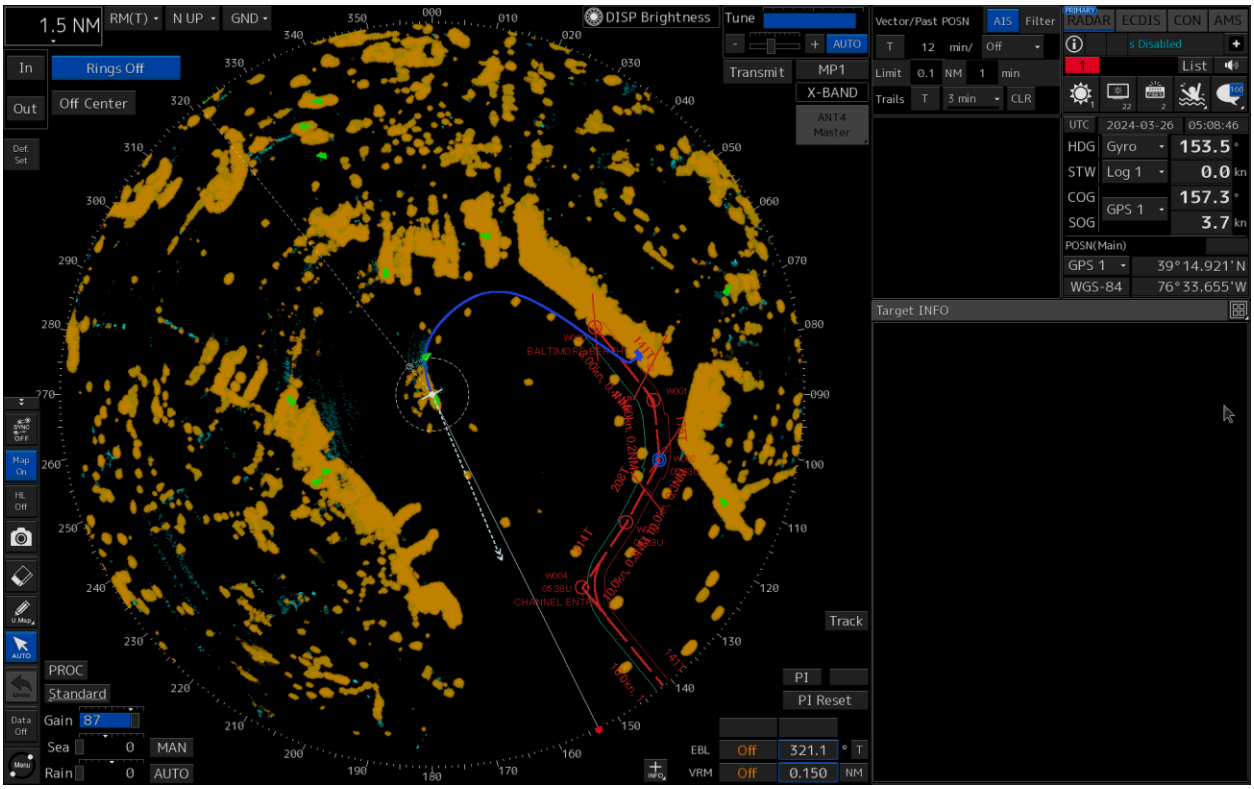

Figure 47. X-Band radar display at approximately 01:09:11 EDT.

Figure 48. ECDIS display at approximately 01:09:15 EDT.

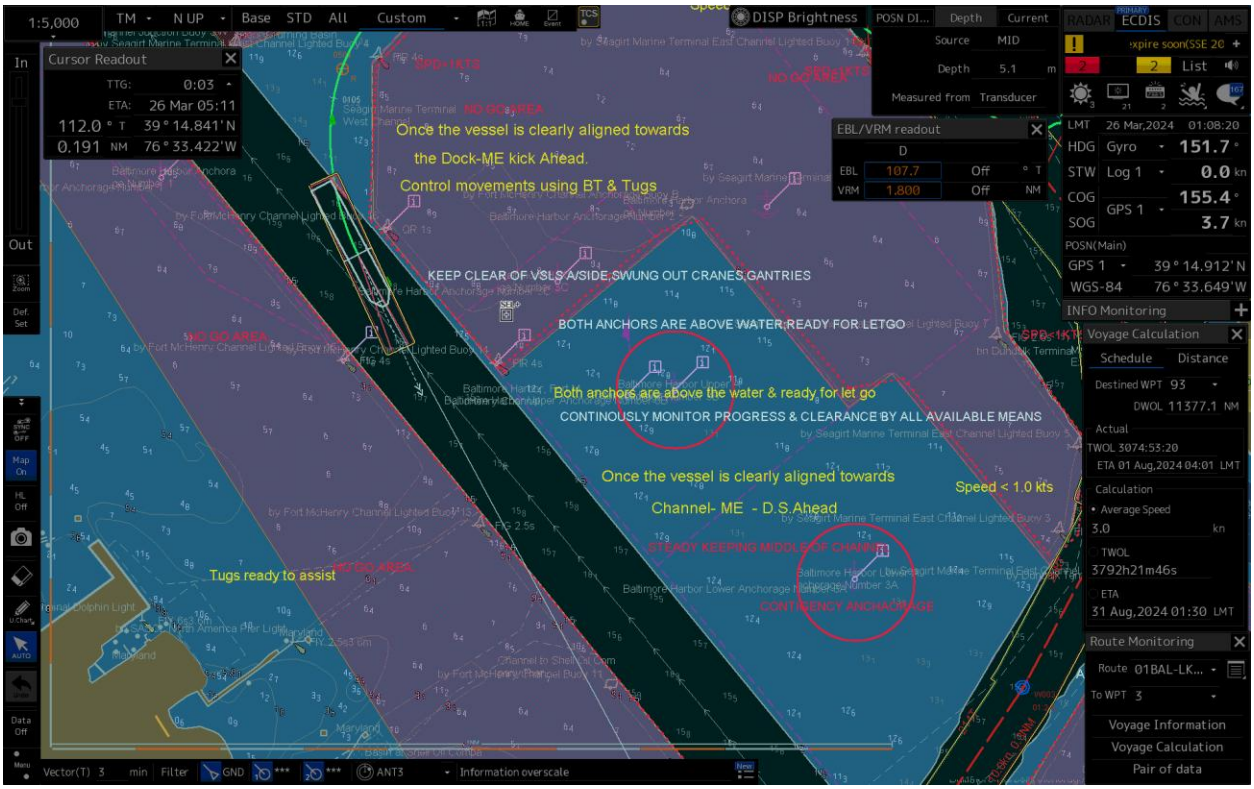

Figure 49. ECDIS display at approximately 01:09:21 EDT.

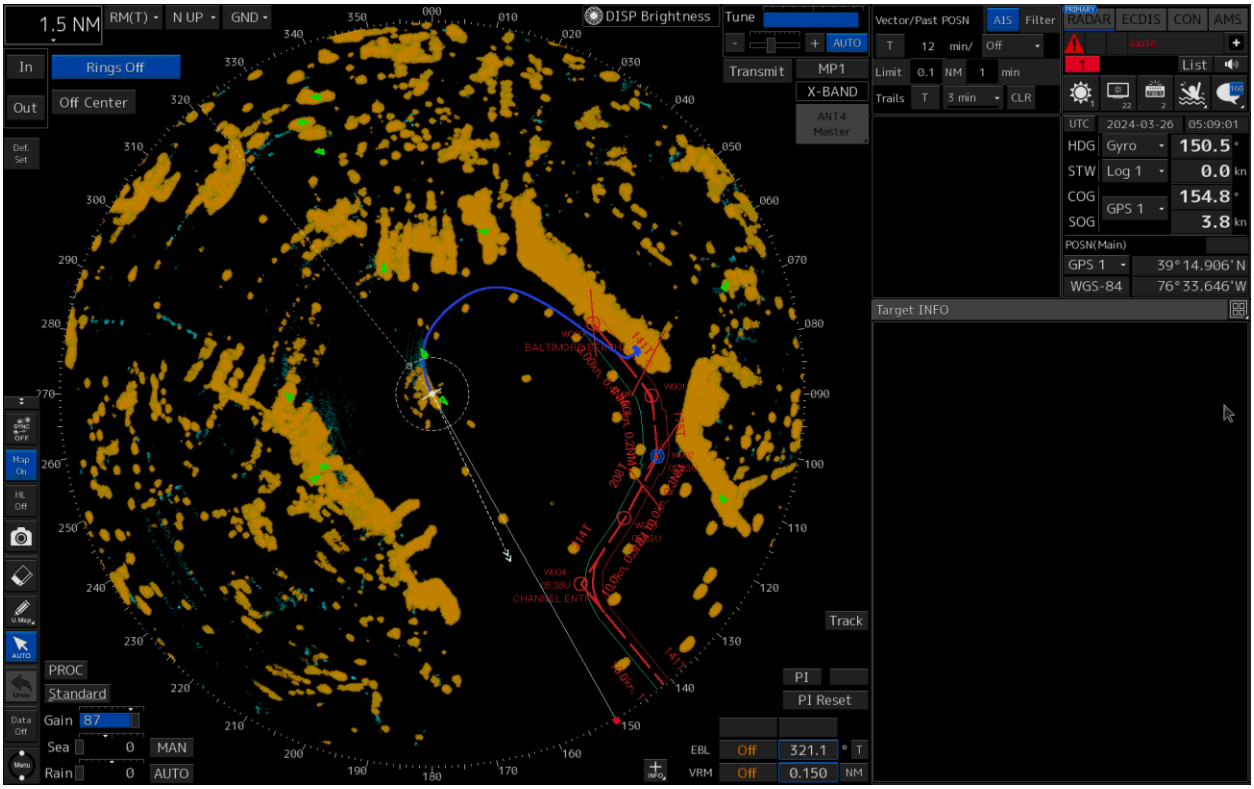

Figure 50. X-Band radar display at approximately 01:09:26 EDT.

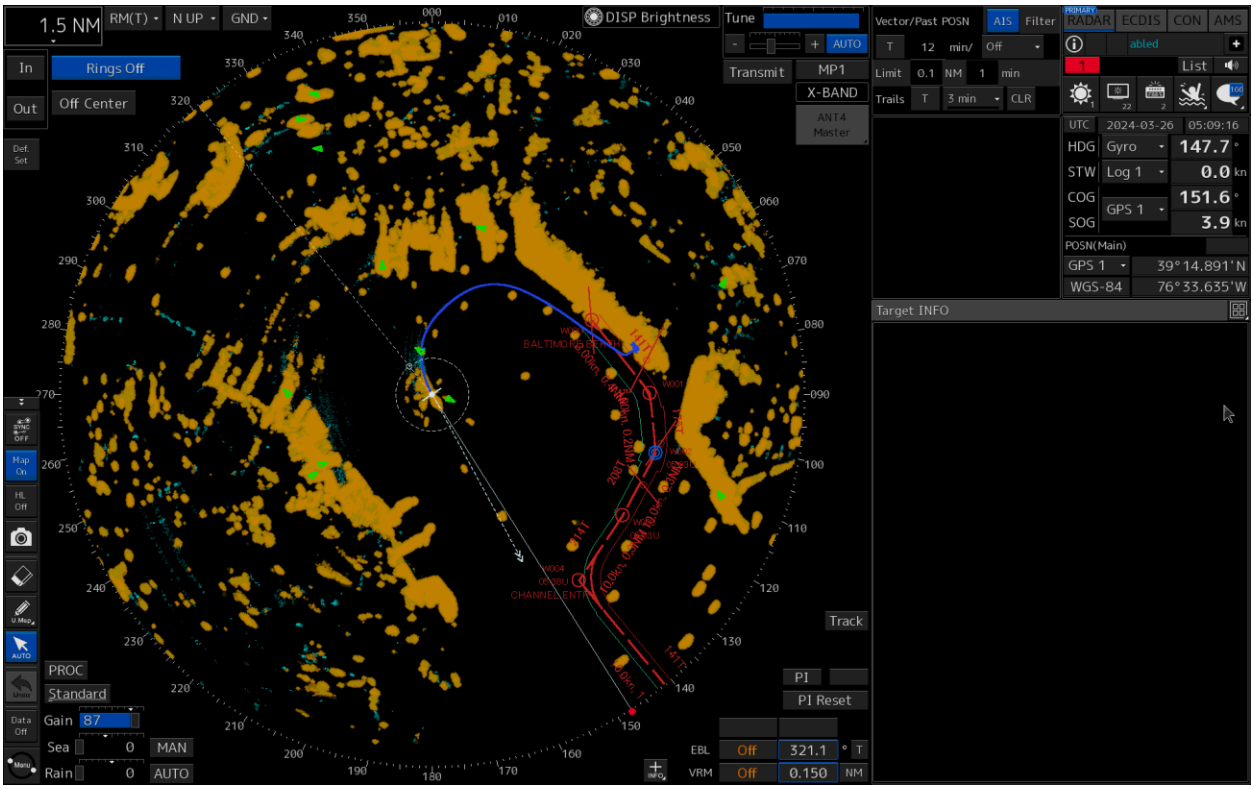

Figure 51. X-Band radar display at approximately 01:09:41 EDT.

Figure 52. ECDIS display at approximately 01:09:46 EDT. Circled are the tugboats, *Bridget McAllister* and *Eric McAllister*.

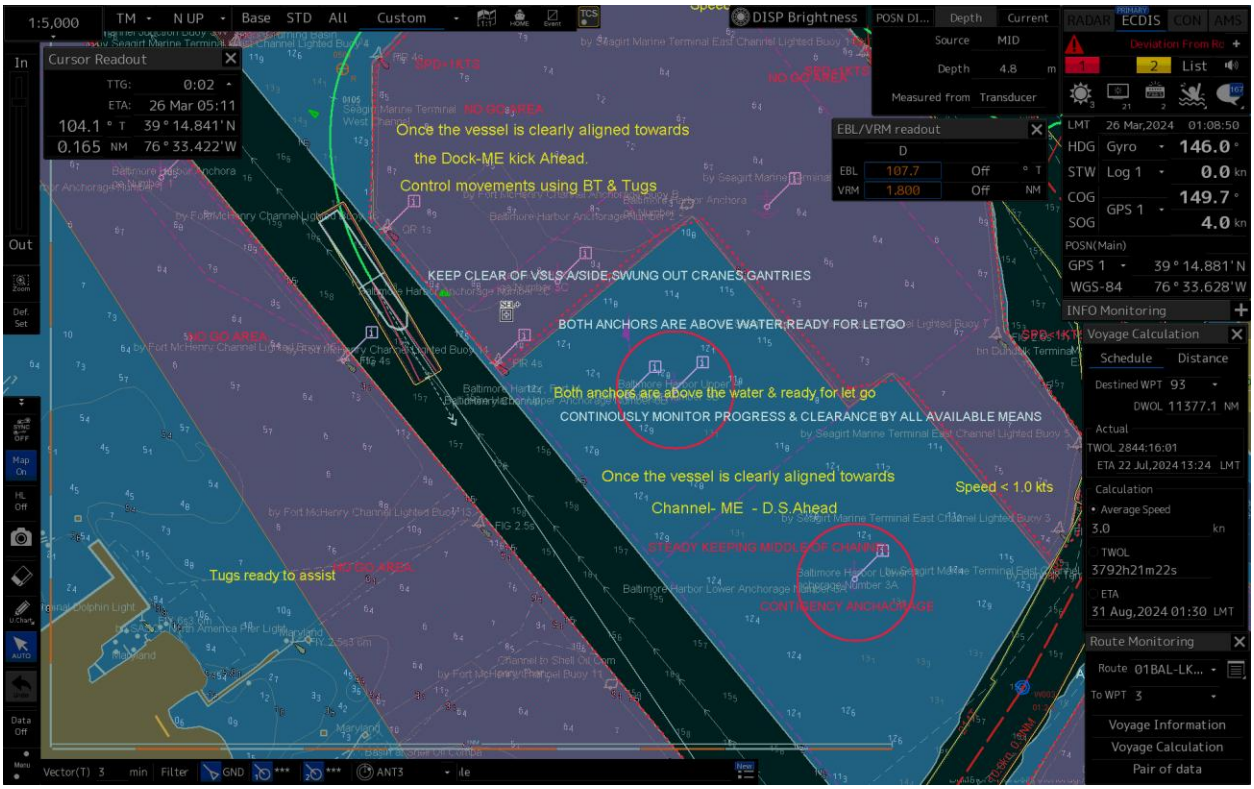

Figure 53. ECDIS display at approximately 01:09:51 EDT.

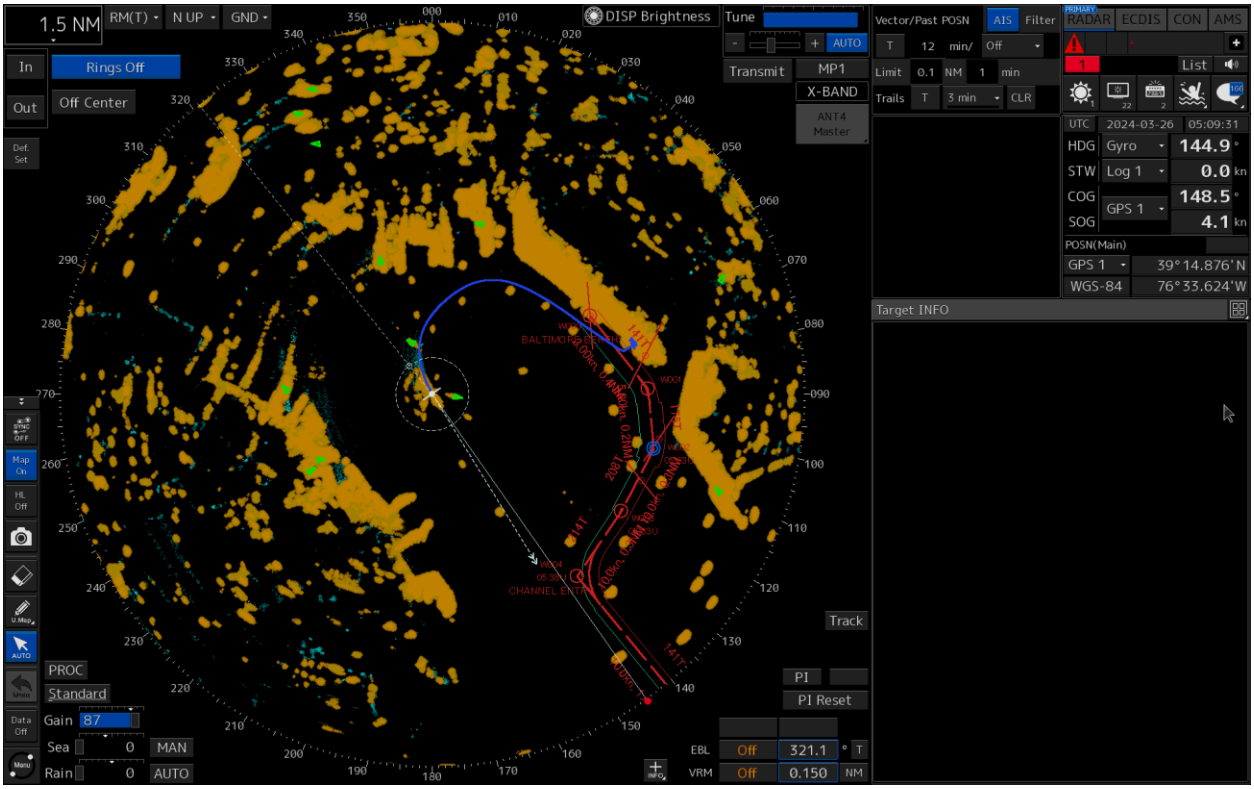

Figure 54. X-Band radar display at approximately 01:09:56 EDT.

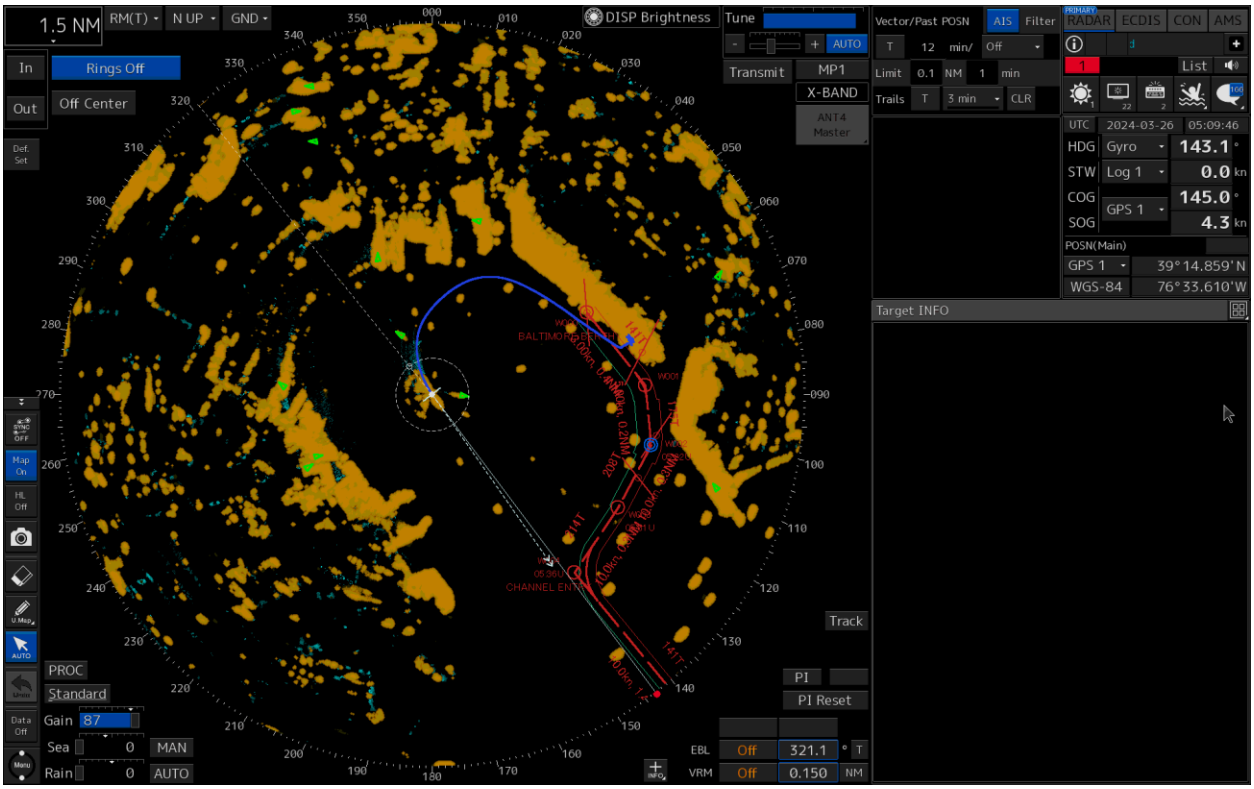

Figure 55. X-Band radar display at approximately 01:10:11 EDT.

Figure 56. ECDIS display at approximately 01:10:16 EDT.

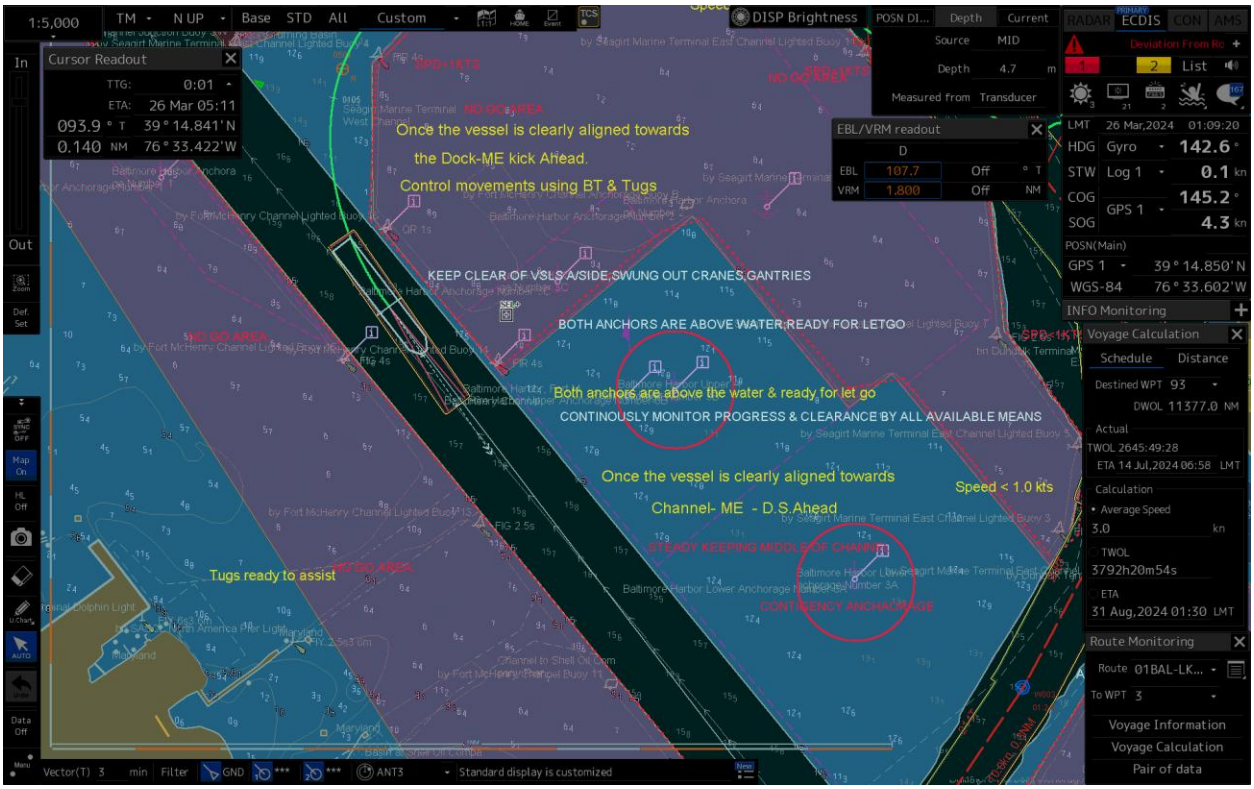

Figure 57. ECDIS display at approximately 01:10:21 EDT.

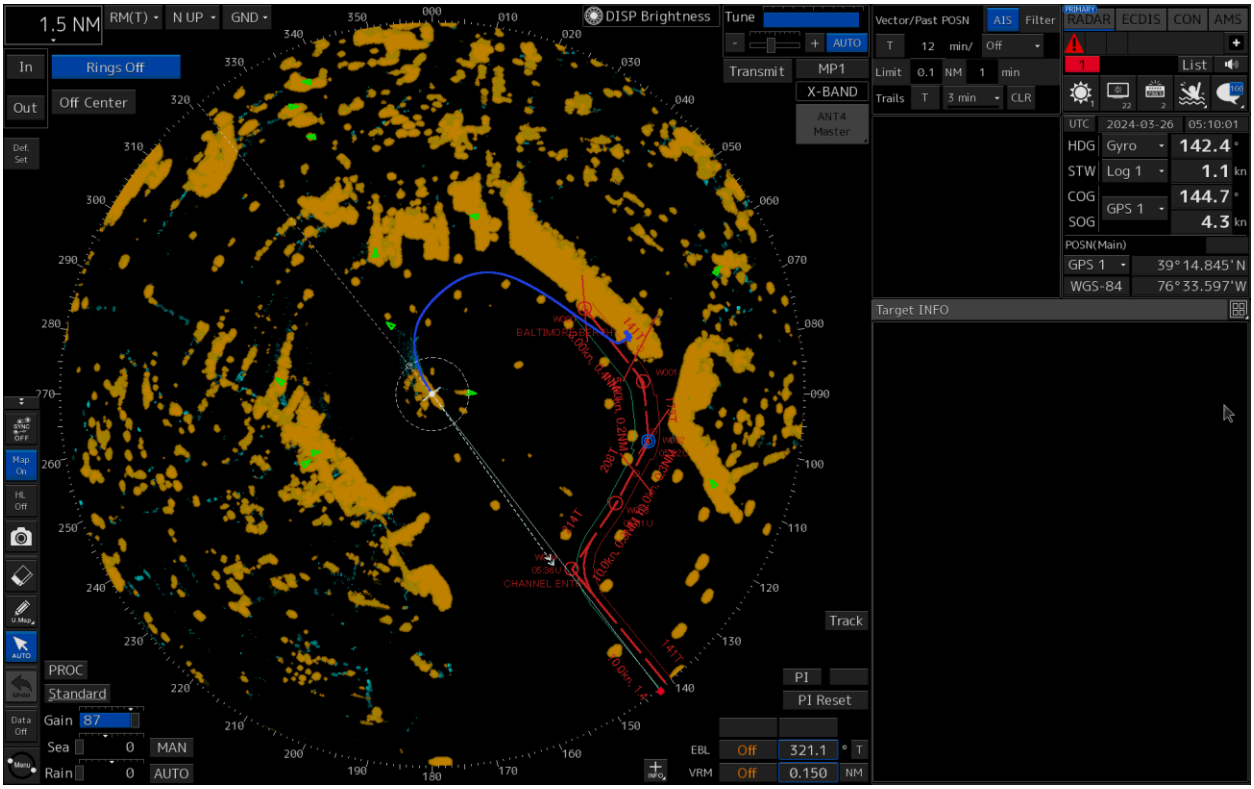

Figure 58. X-Band radar display at approximately 01:10:26 EDT.

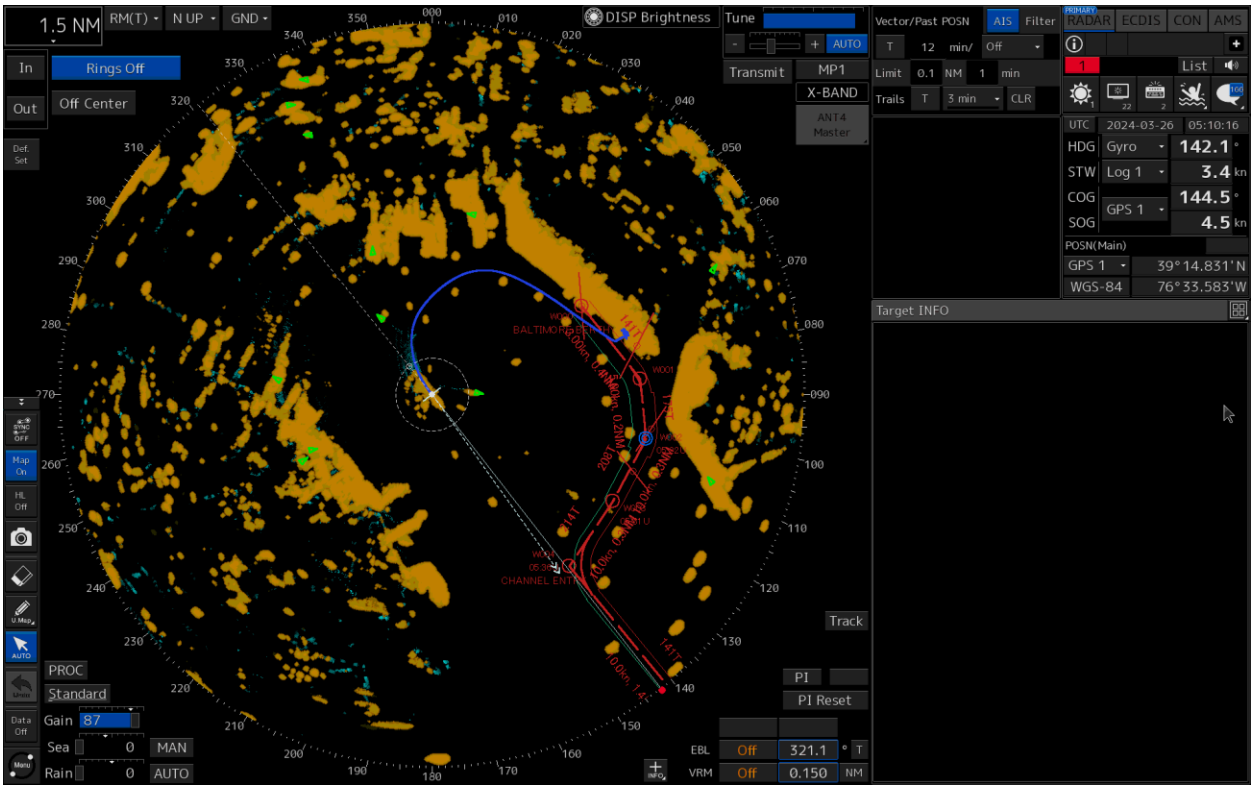

Figure 59. X-Band radar display at approximately 01:10:41 EDT.

Figure 60. ECDIS display at approximately 01:10:46 EDT.

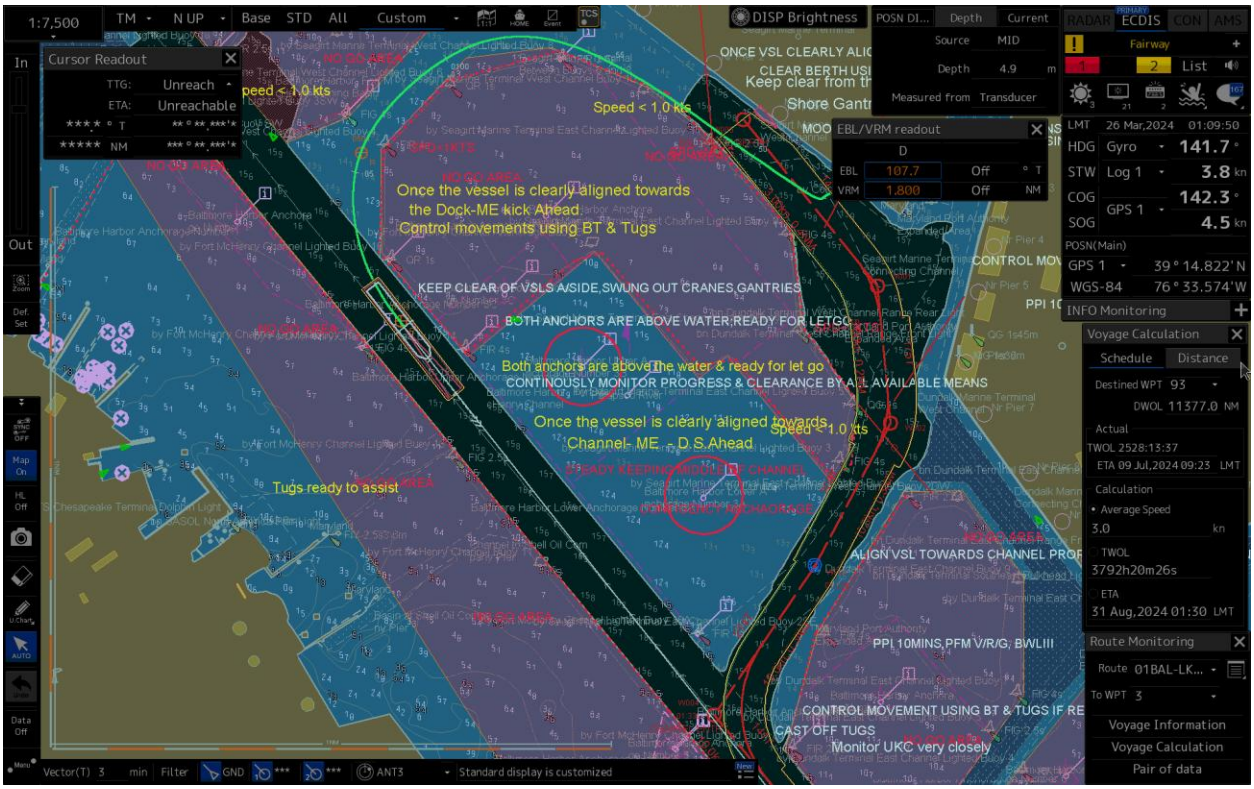

Figure 61. ECDIS display at approximately 01:10:51 EDT.

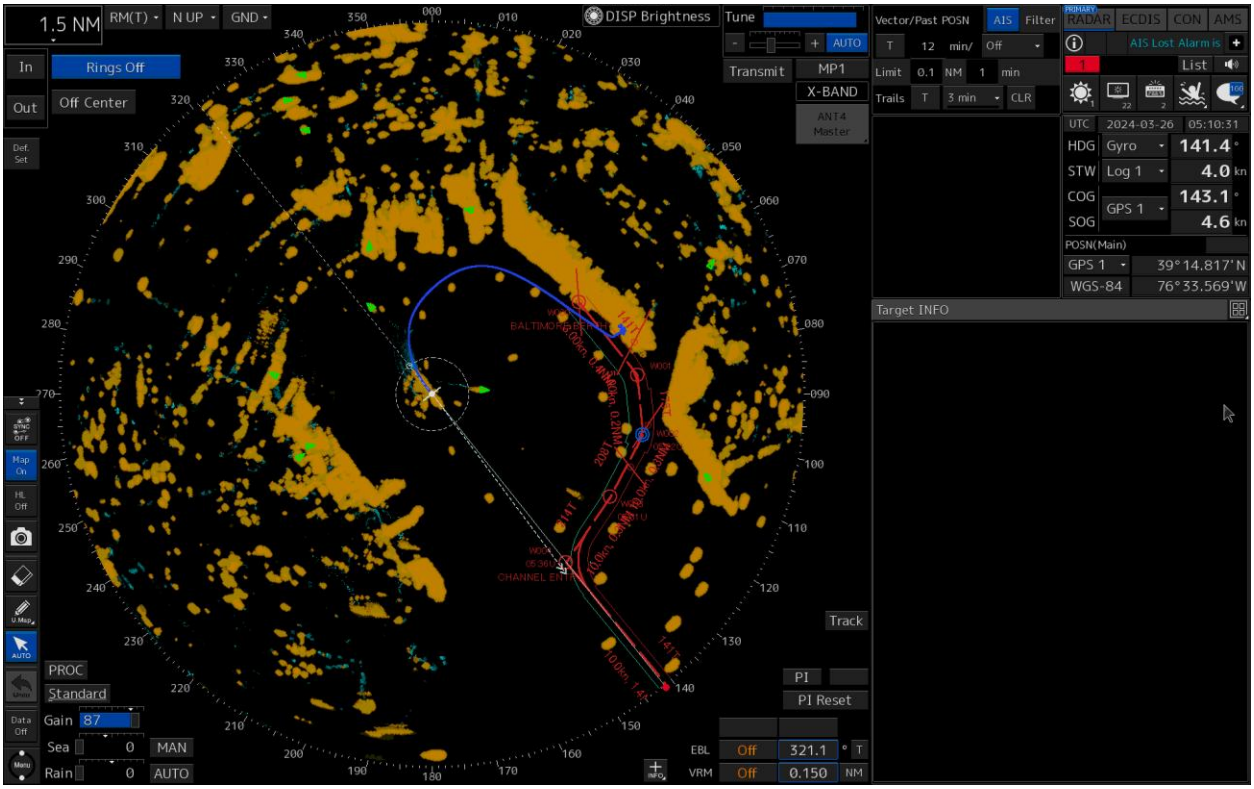

Figure 62. X-Band radar display at approximately 01:10:56 EDT.

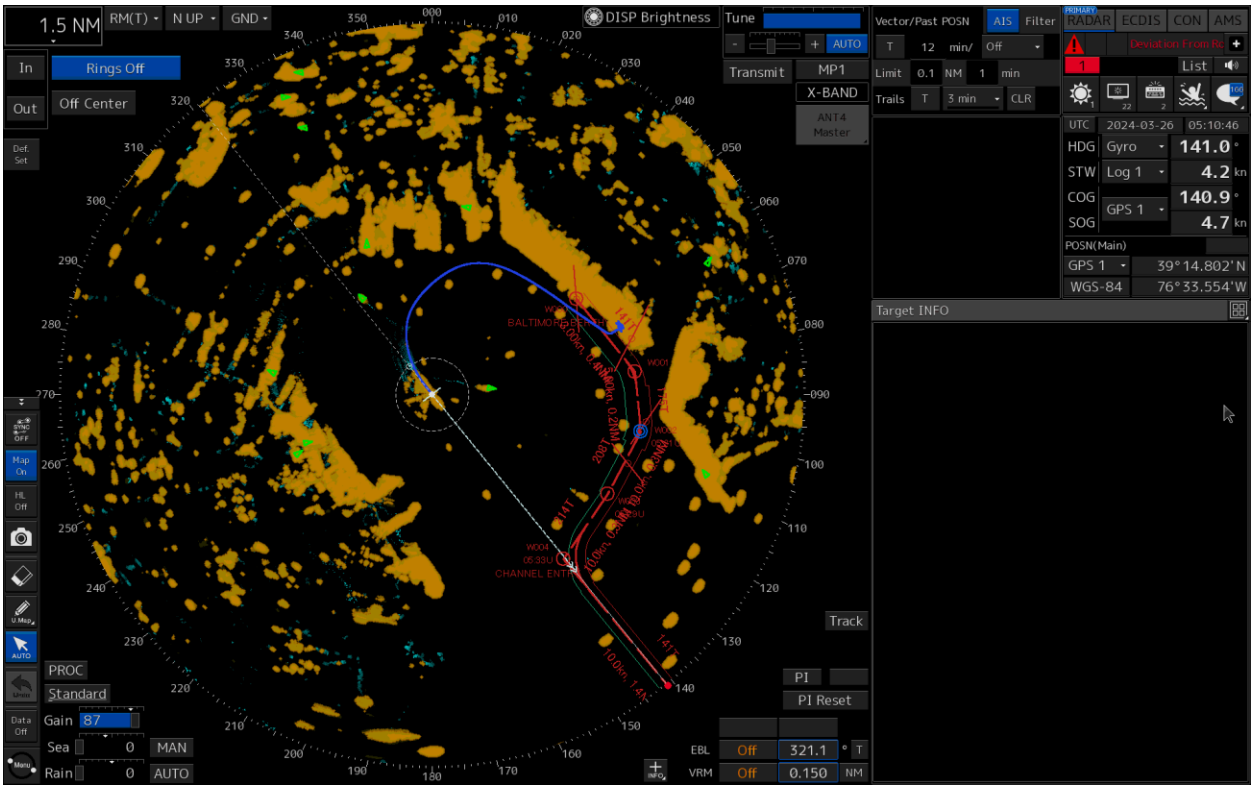

Figure 63. X-Band radar display at approximately 01:11:11 EDT.

Figure 64. ECDIS display at approximately 01:11:16 EDT.

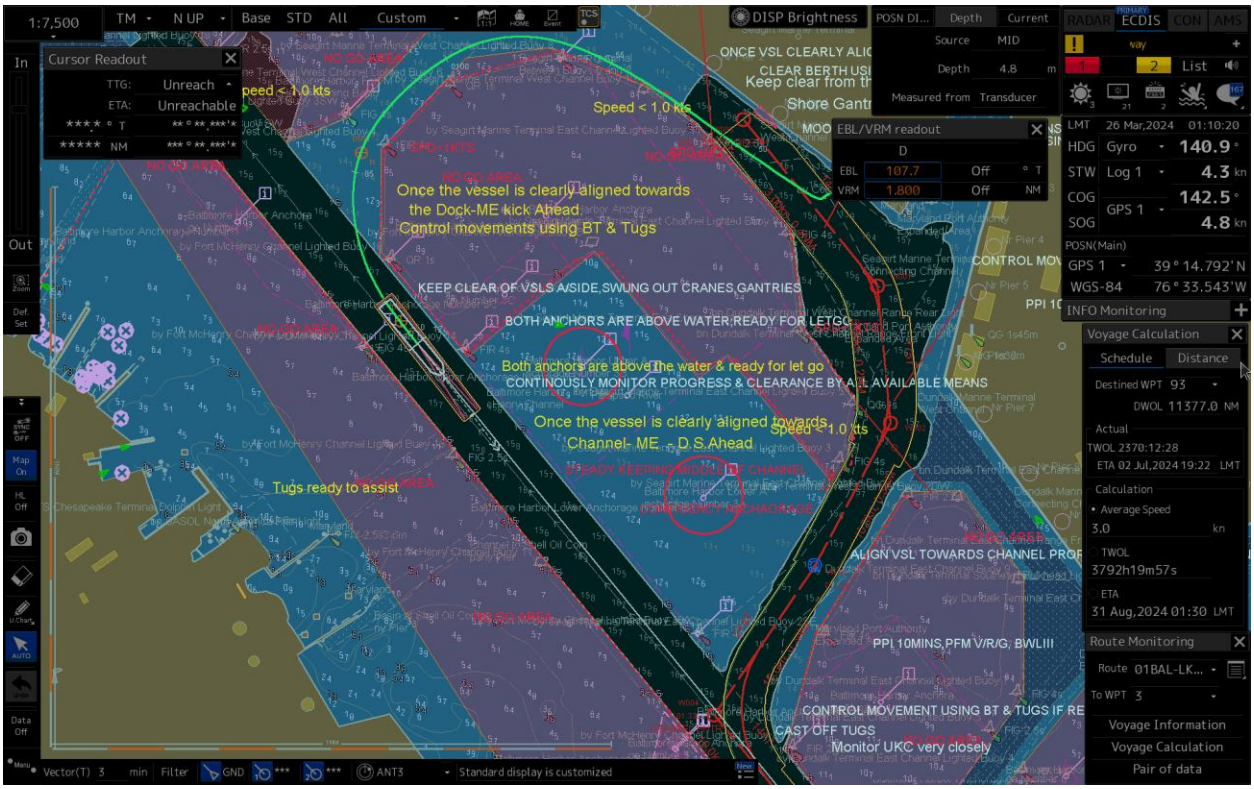

Figure 65. ECDIS display at approximately 01:11:21 EDT.

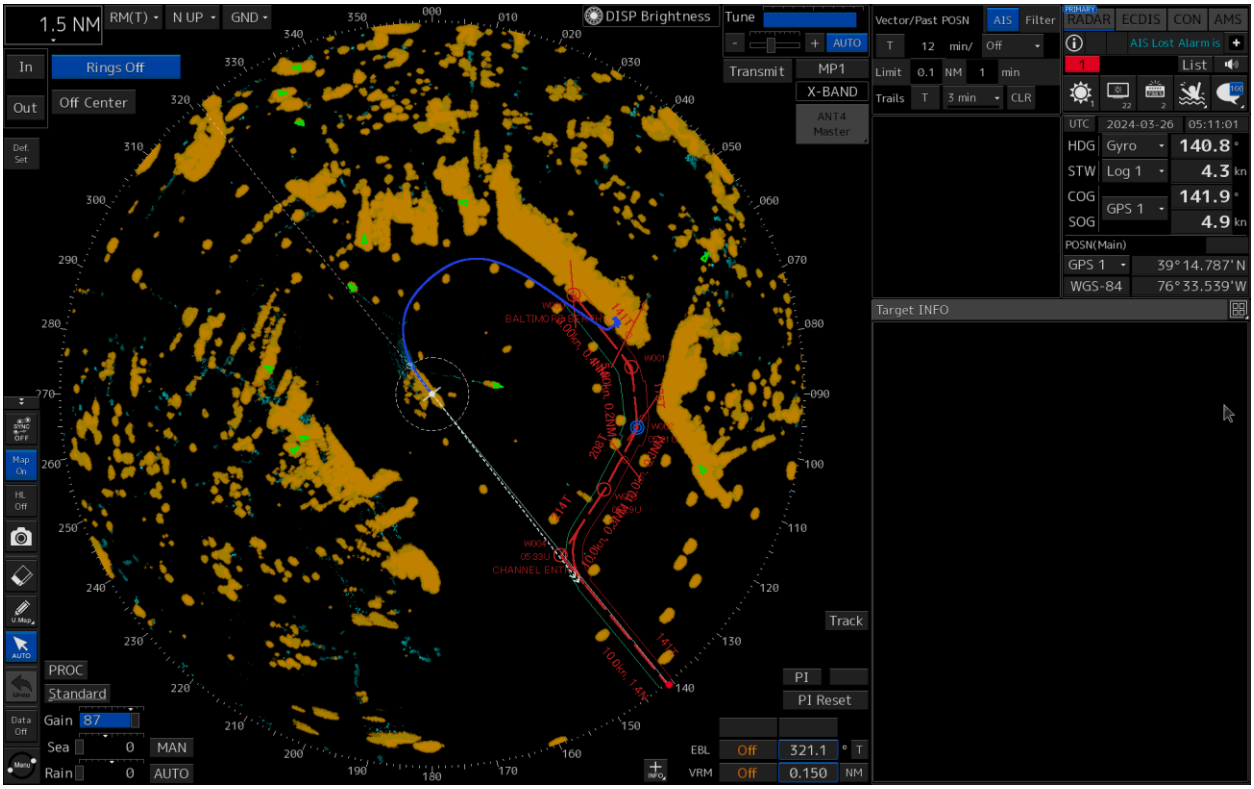

Figure 66. X-Band radar display at approximately 01:11:26 EDT.

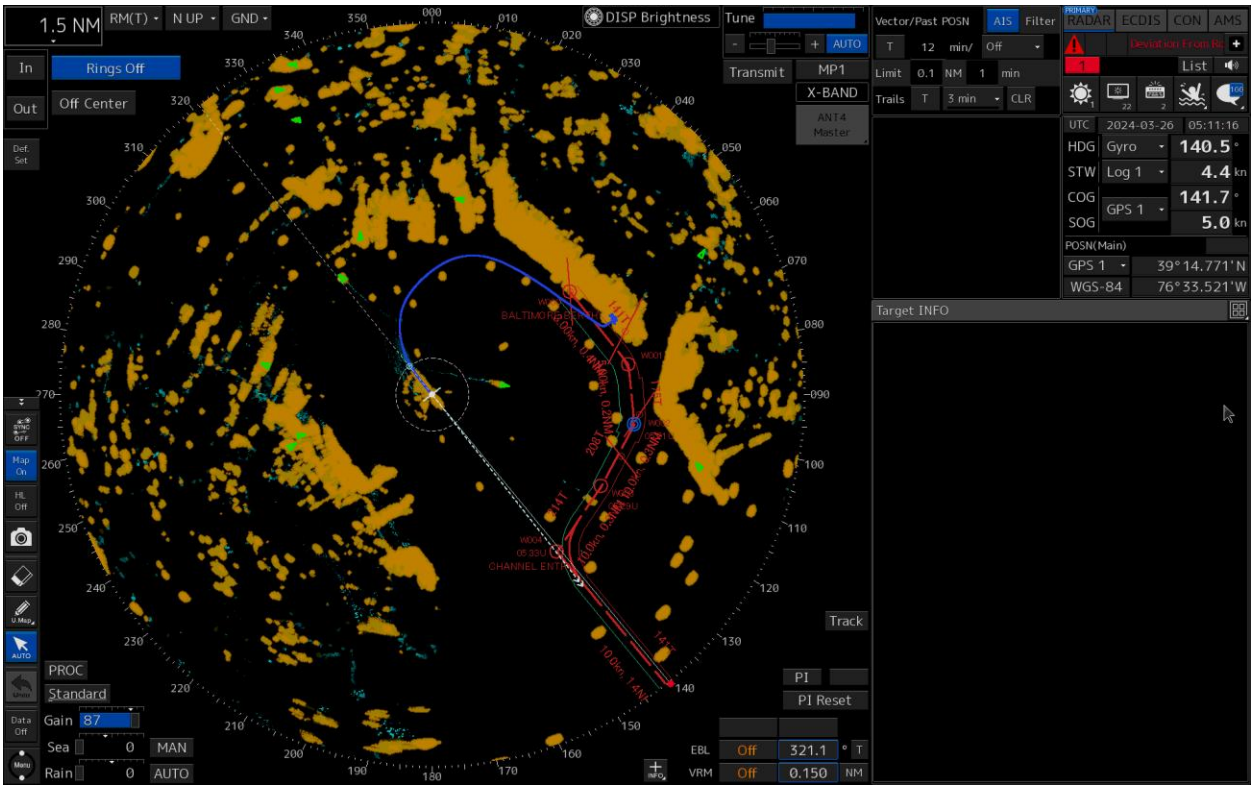

Figure 67. X-Band radar display at approximately 01:11:41 EDT.

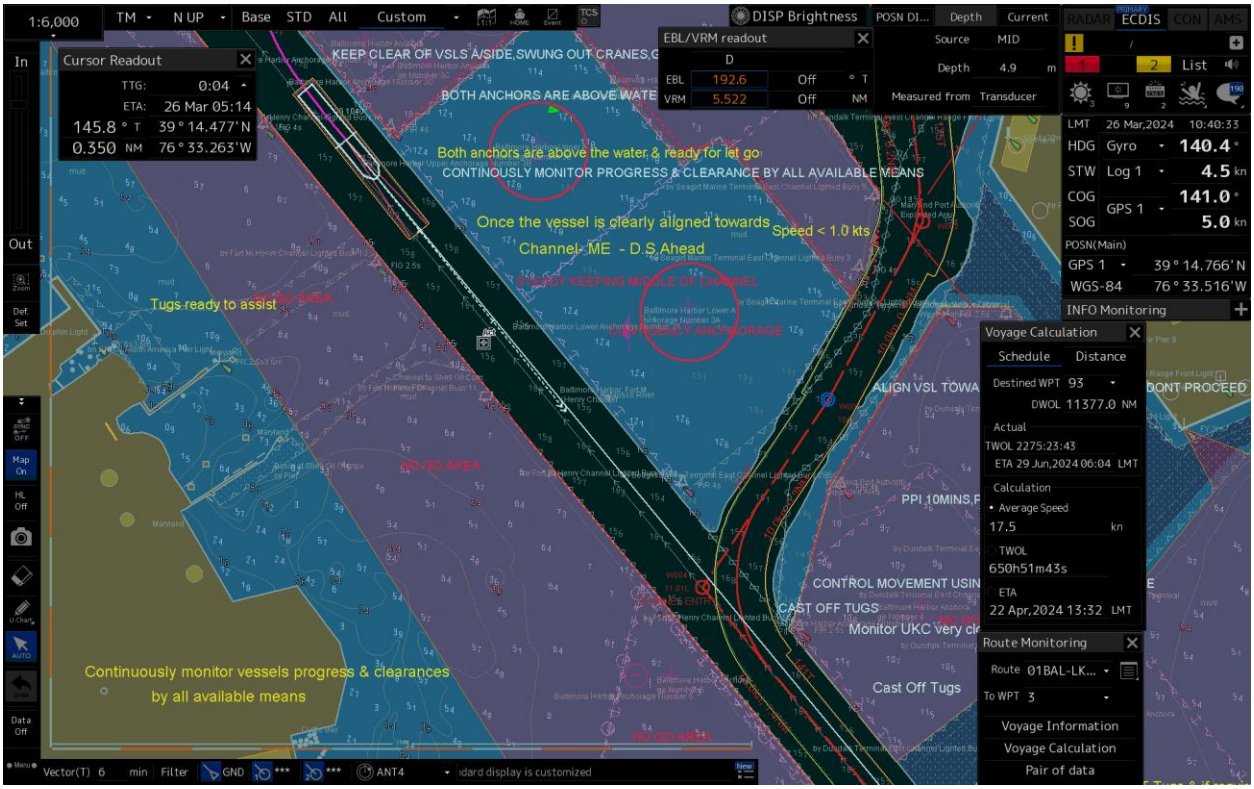

Figure 68. ECDIS display at approximately 01:11:46 EDT.

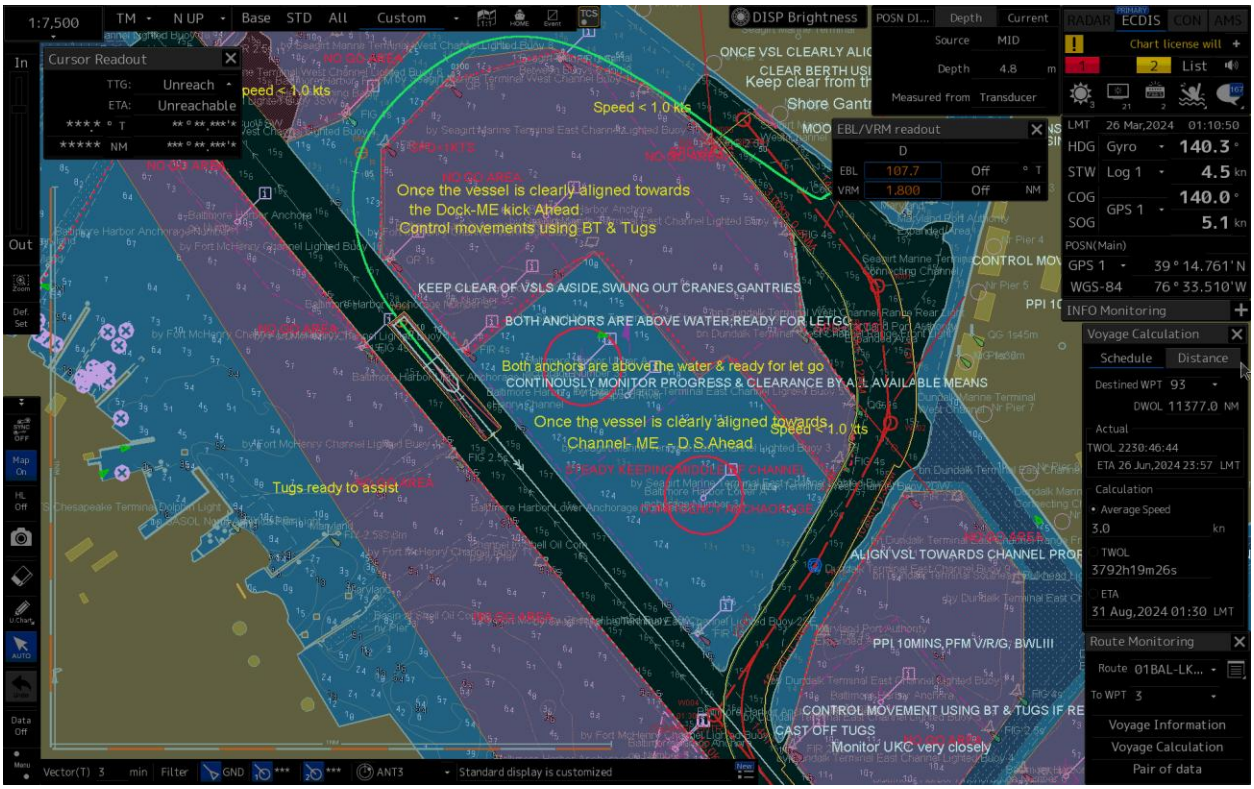

Figure 69. ECDIS display at approximately 01:11:51 EDT.

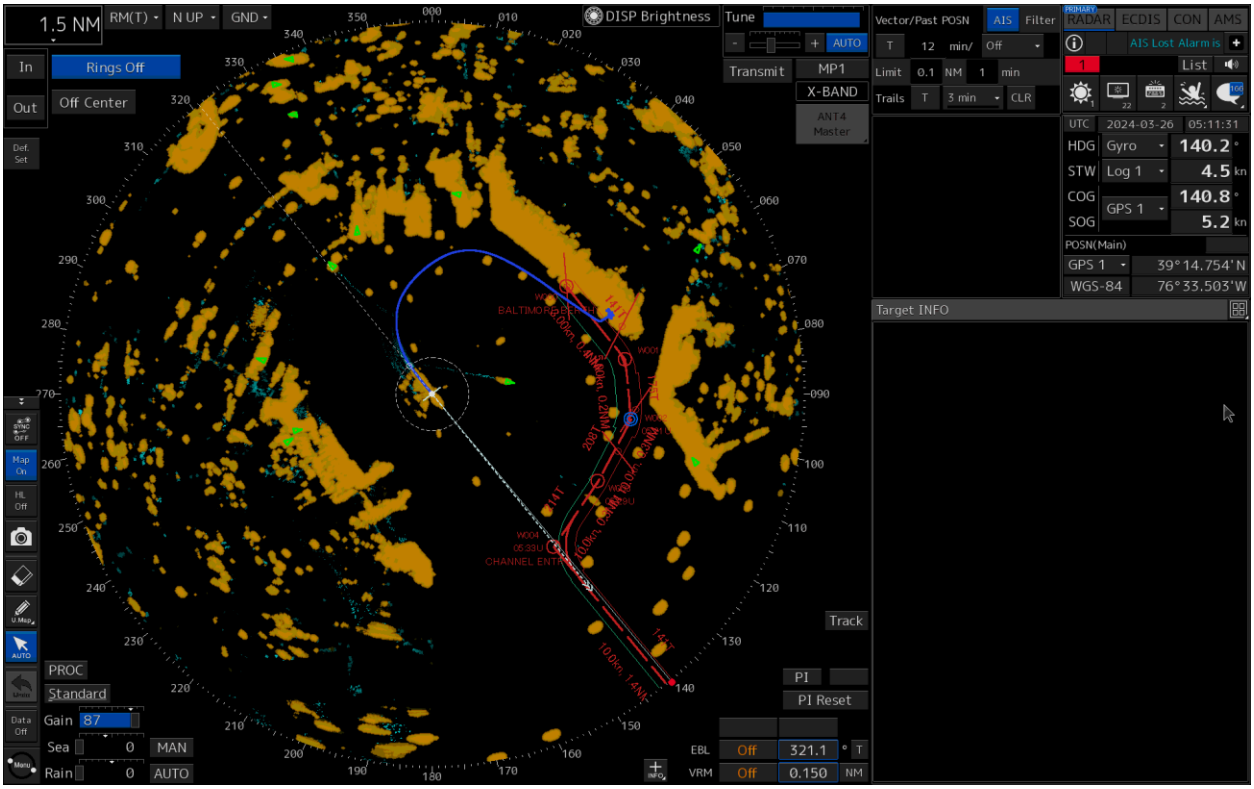

Figure 70. X-Band radar display at approximately 01:11:56 EDT.

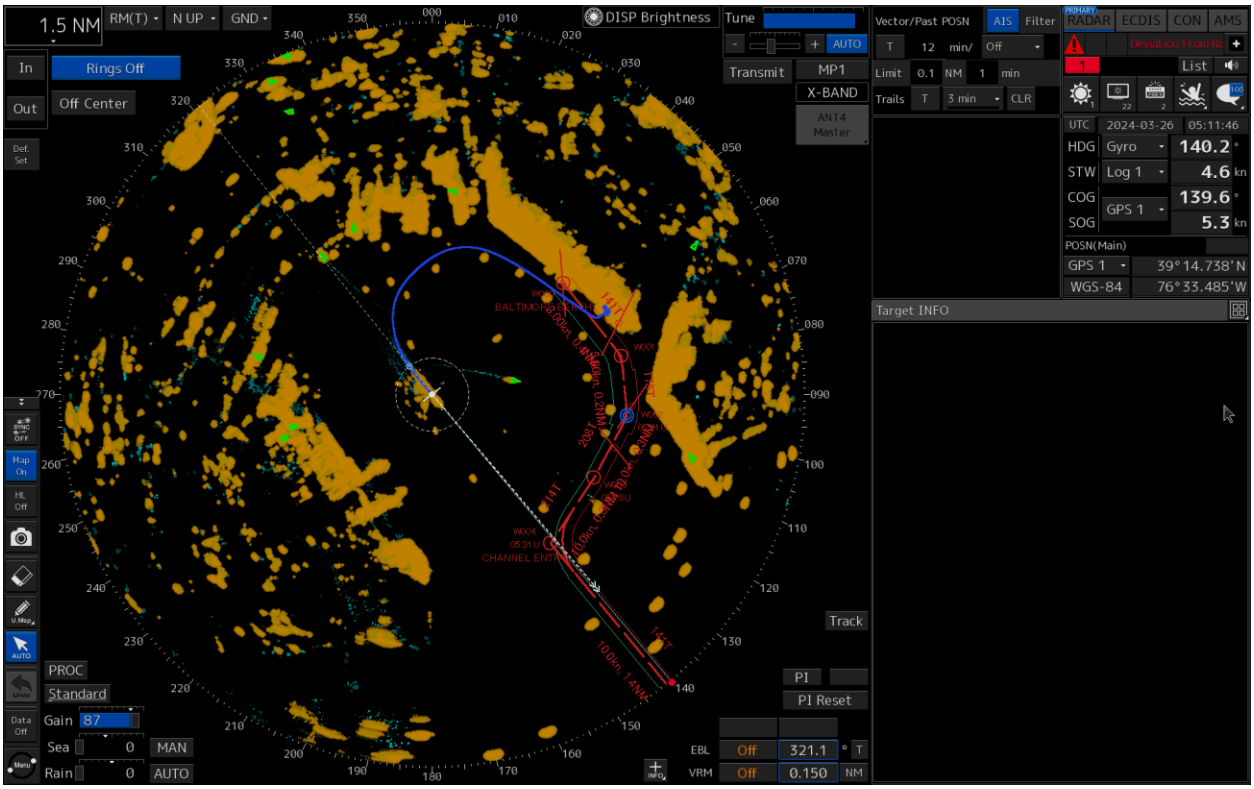

Figure 71. X-Band radar display at approximately 01:12:11 EDT.

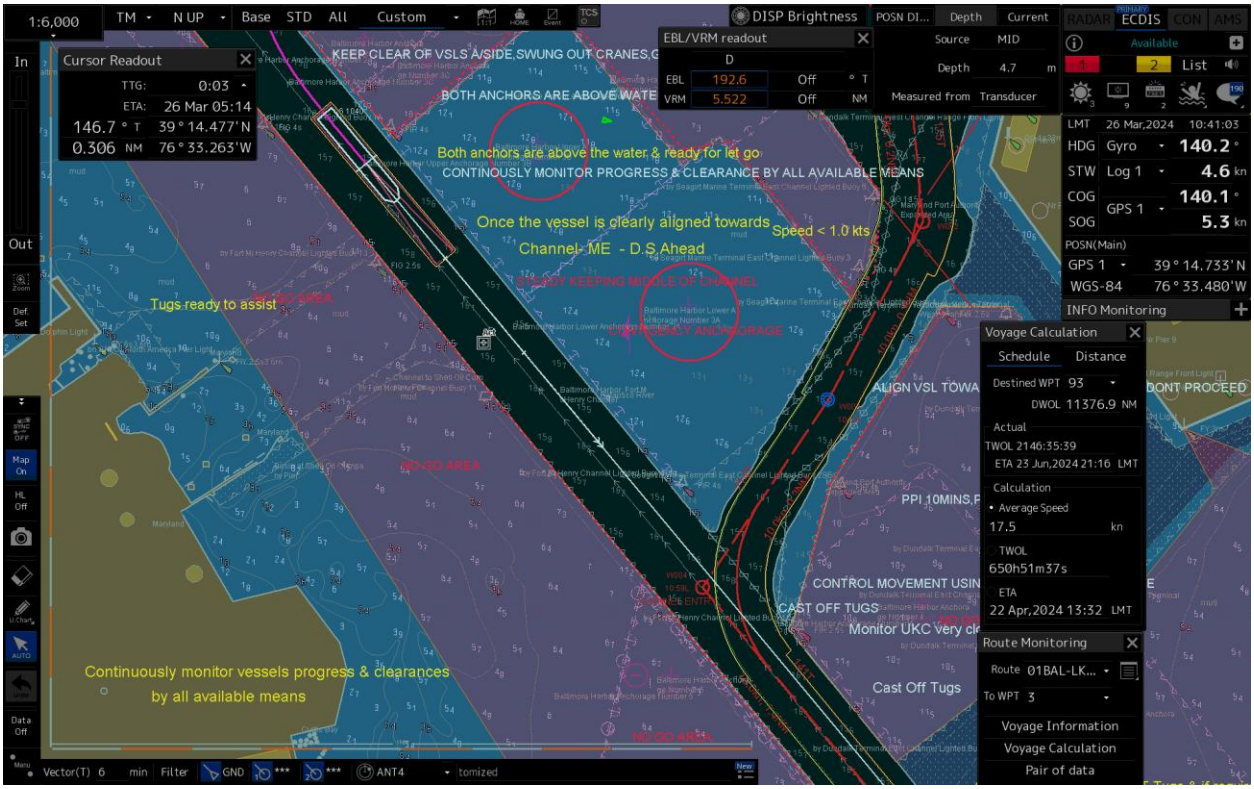

Figure 72. ECDIS display at approximately 01:12:16 EDT.

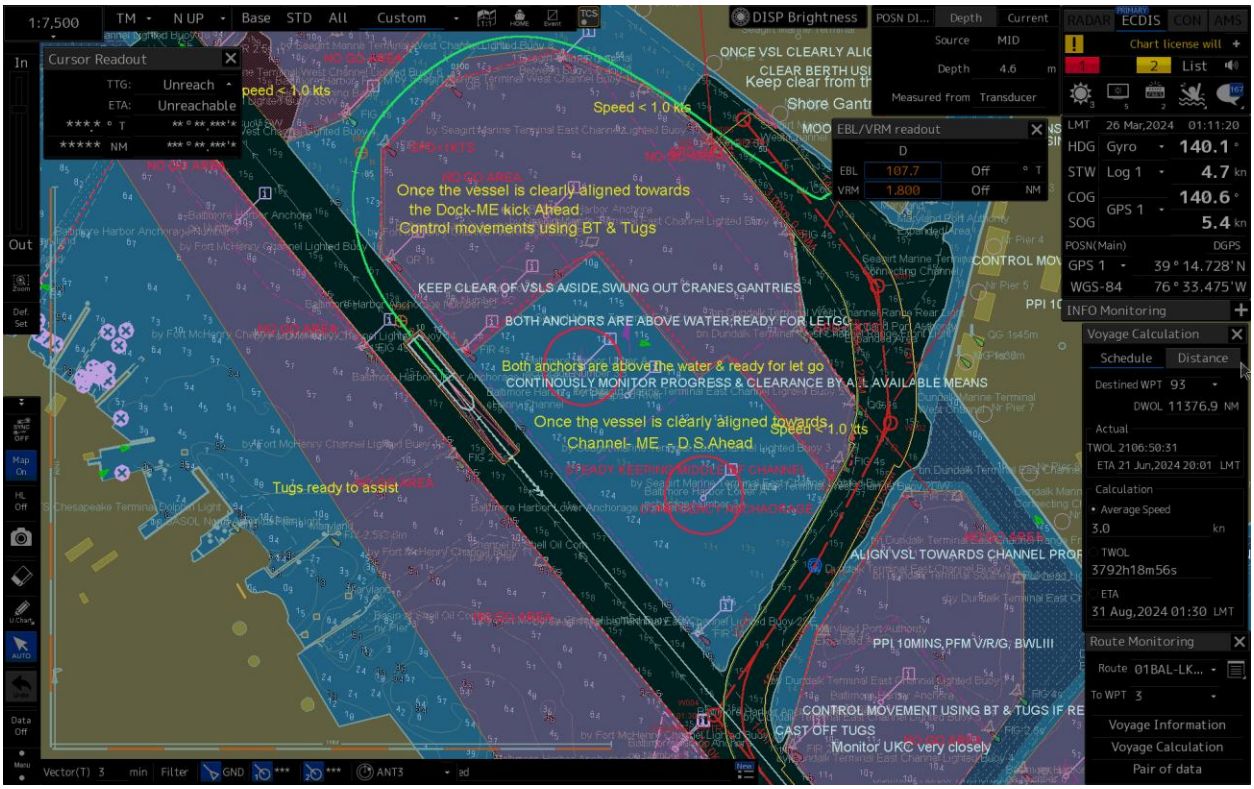

Figure 73. ECDIS display at approximately 01:12:21 EDT.

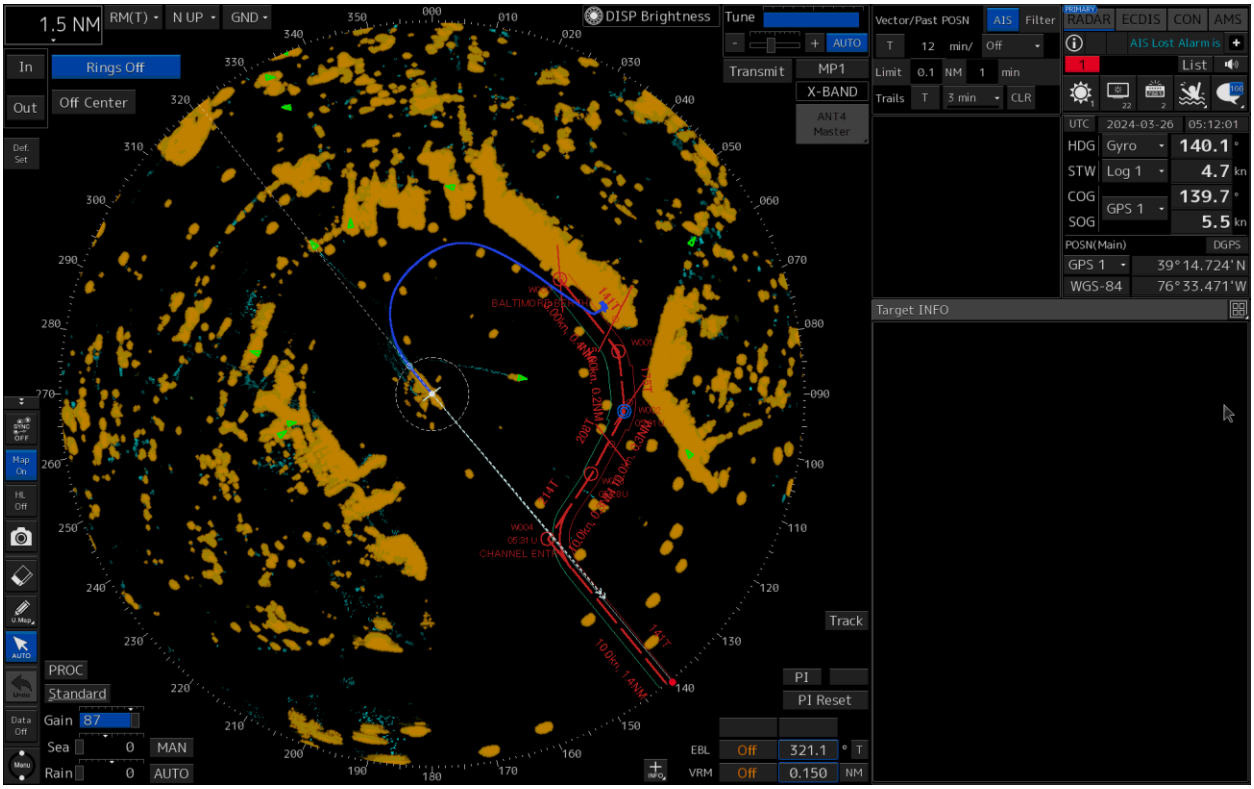

Figure 74. X-Band radar display at approximately 01:12:26 EDT.

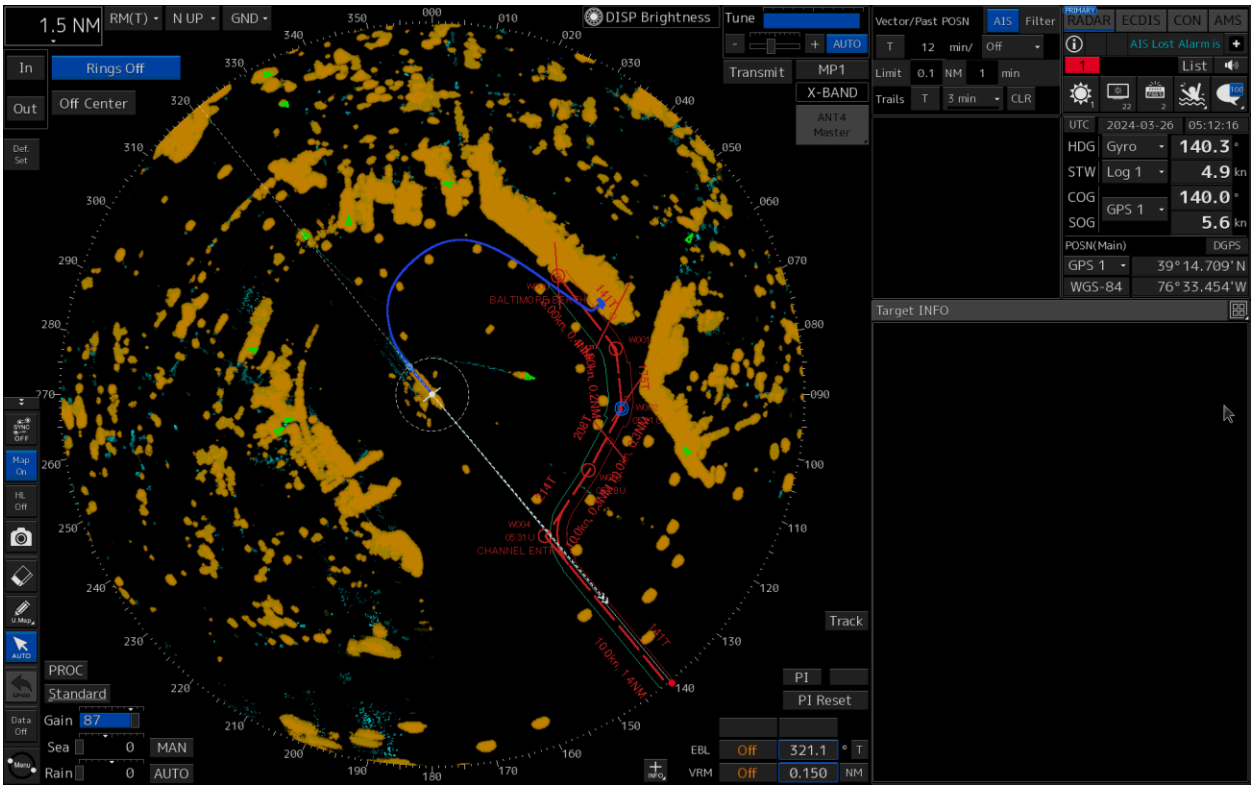

Figure 75. X-Band radar display at approximately 01:12:41 EDT.

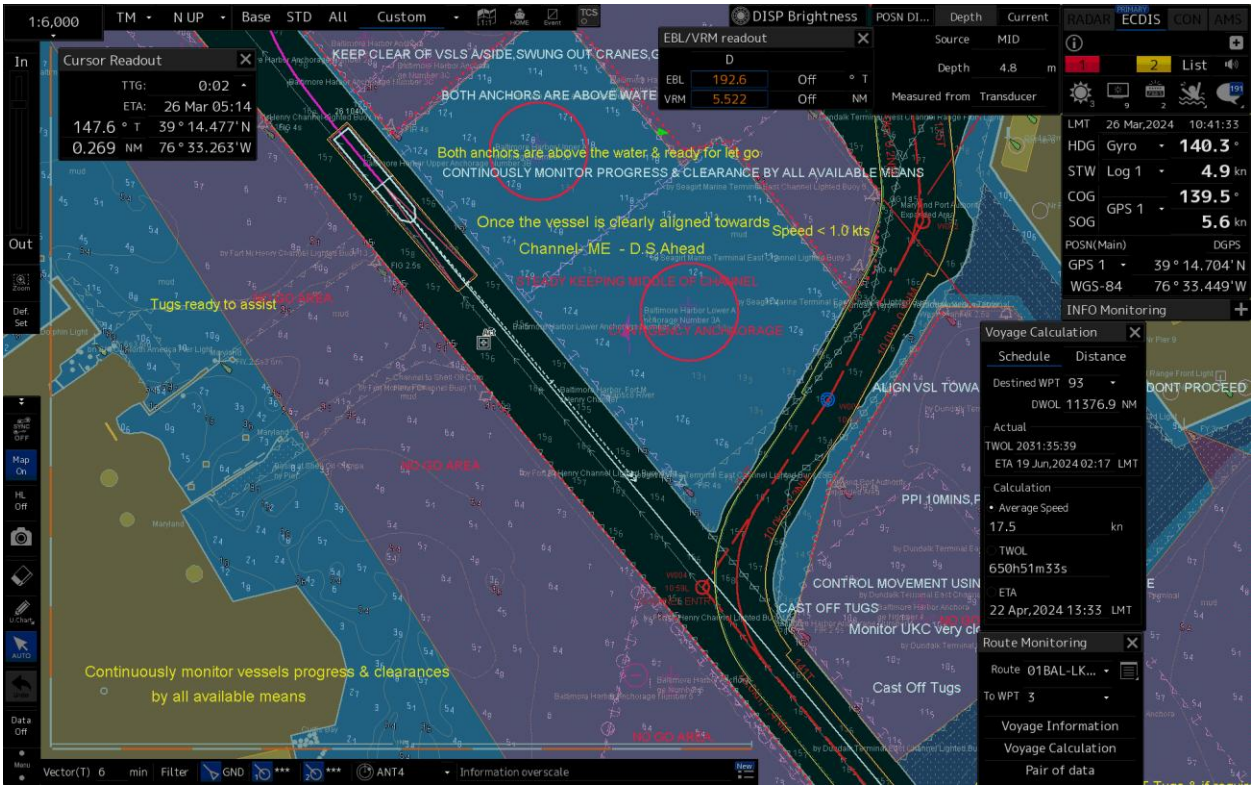

Figure 76. ECDIS display at approximately 01:12:46 EDT.

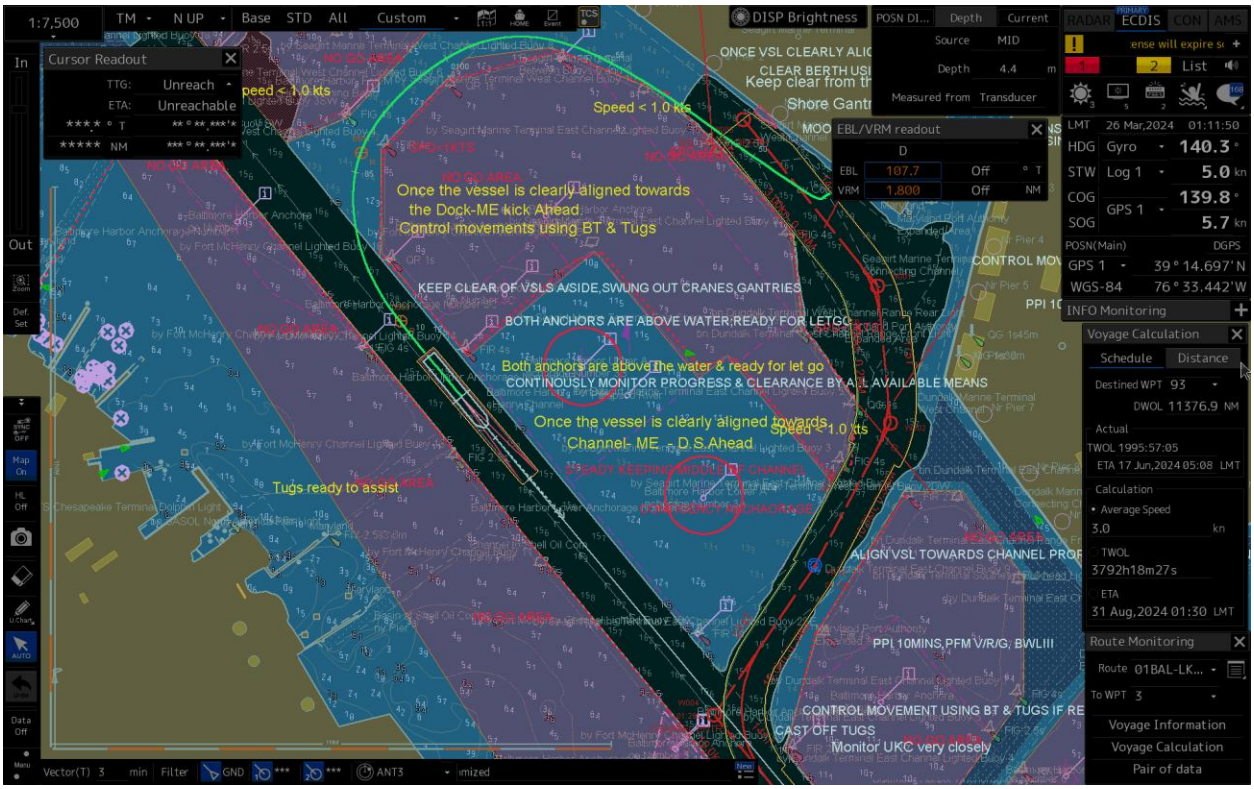

Figure 77. ECDIS display at approximately 01:12:51 EDT.

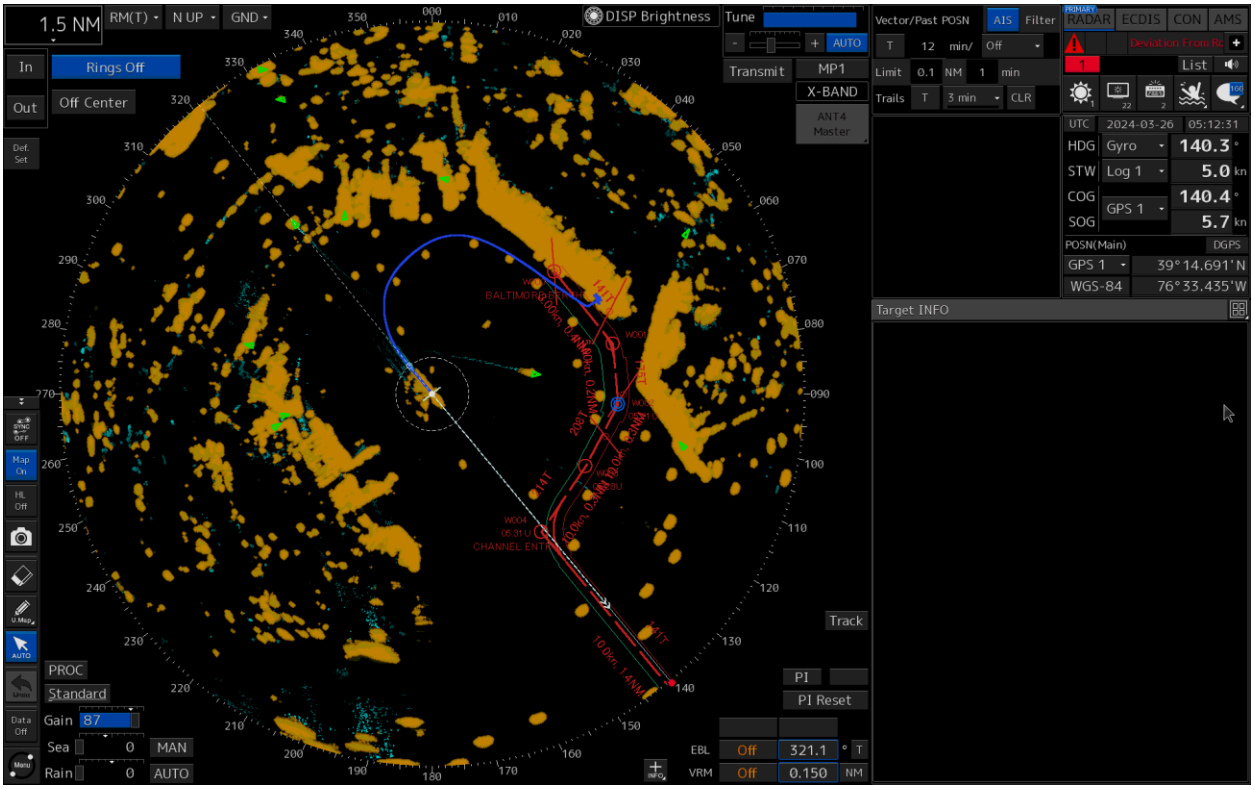

Figure 78. X-Band radar display at approximately 01:12:56 EDT.

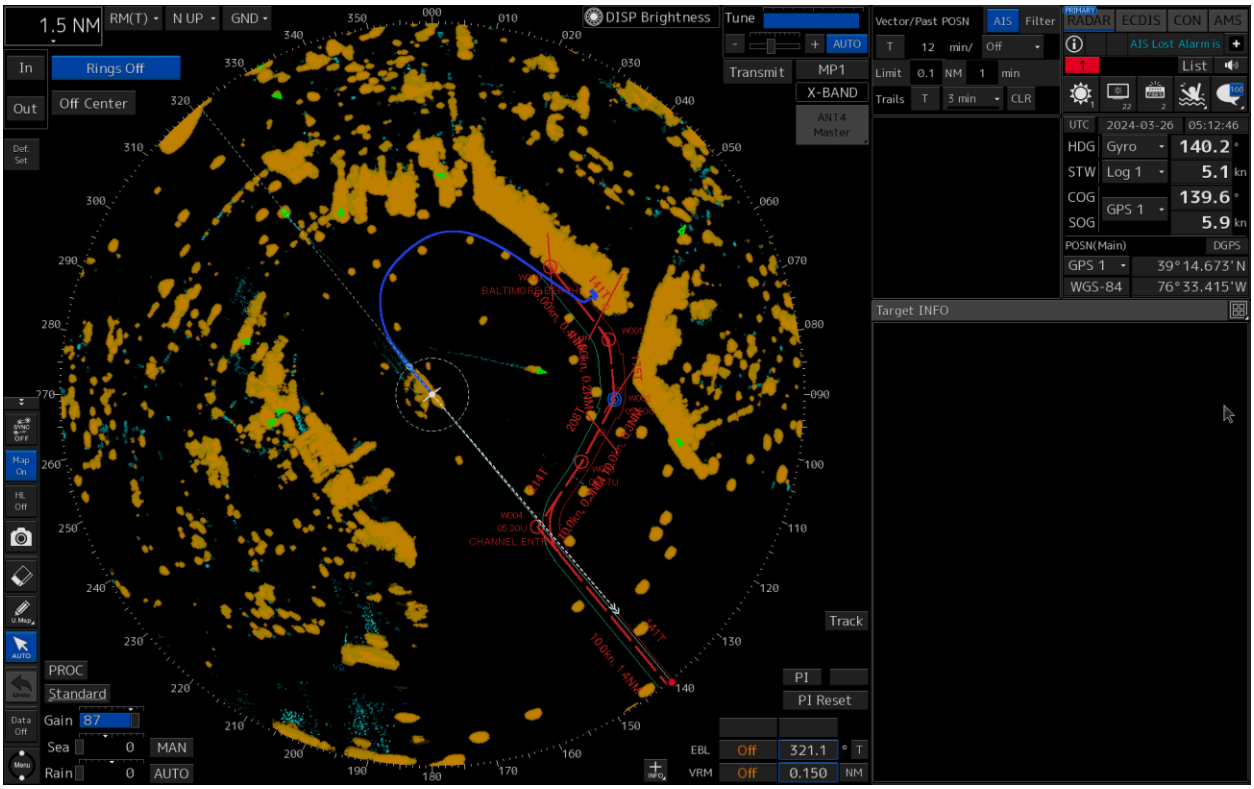

Figure 79. X-Band radar display at approximately 01:13:11 EDT.

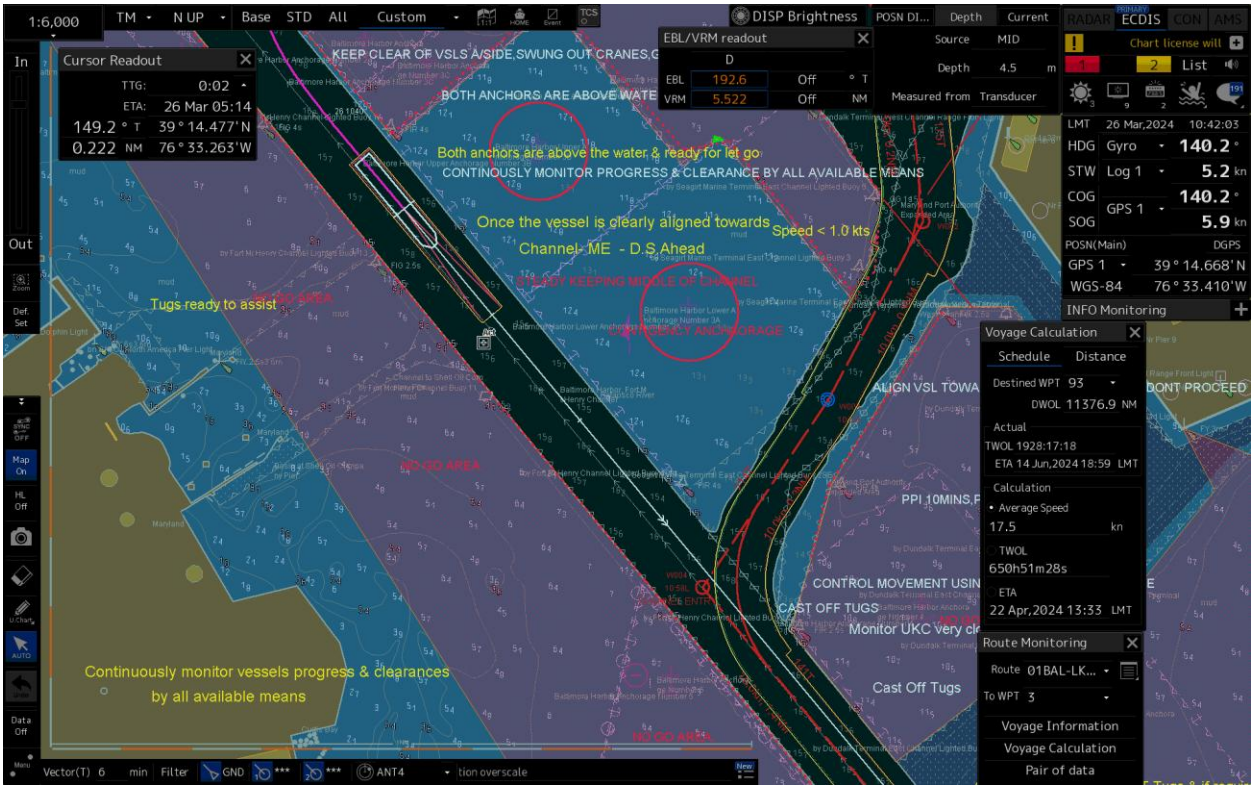

Figure 80. ECDIS display at approximately 01:13:16 EDT.

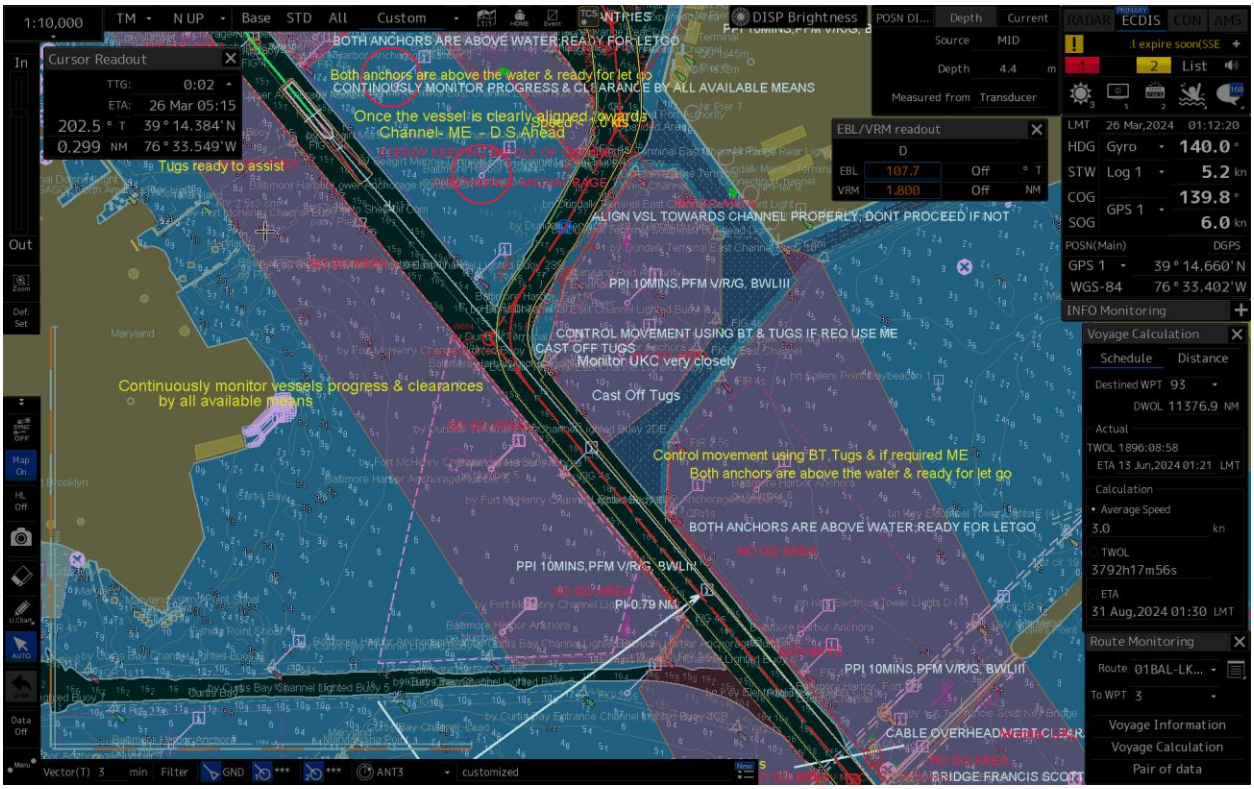

Figure 81. ECDIS display at approximately 01:13:21 EDT.

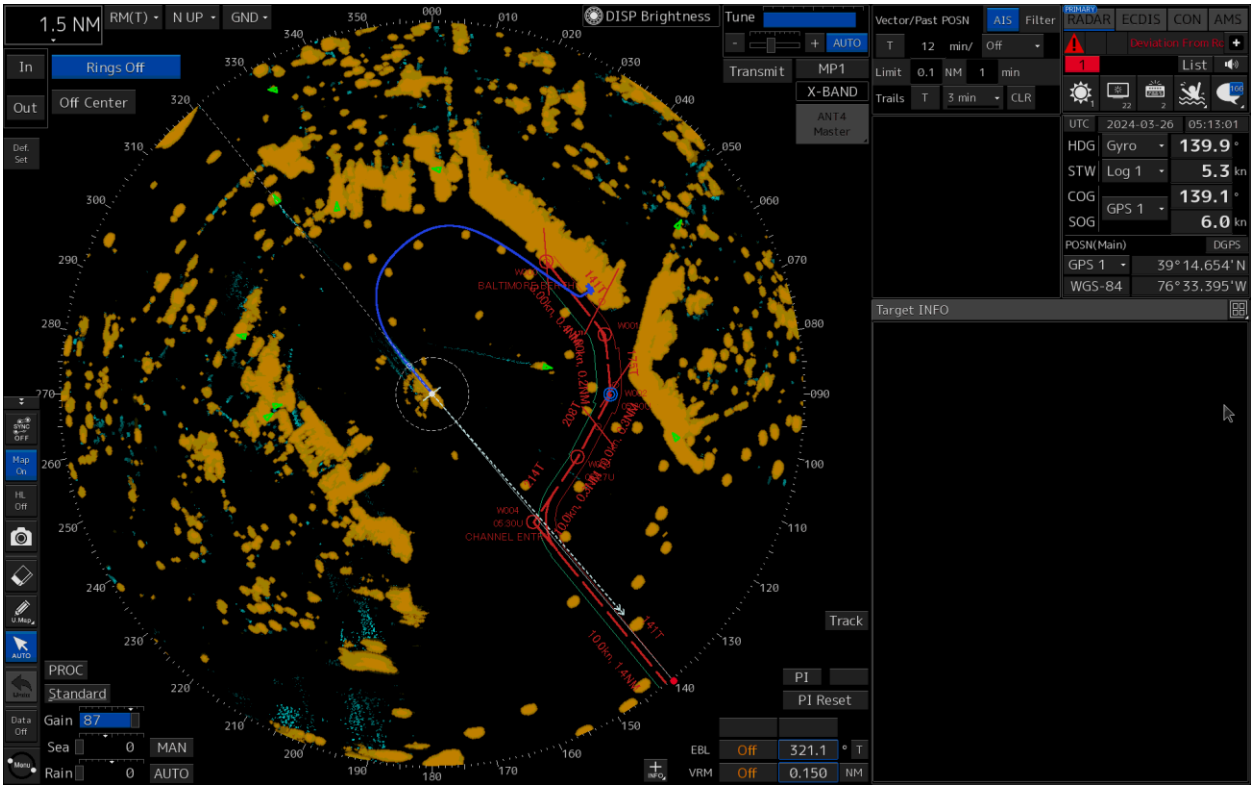

Figure 82. X-Band radar display at approximately 01:13:26 EDT.

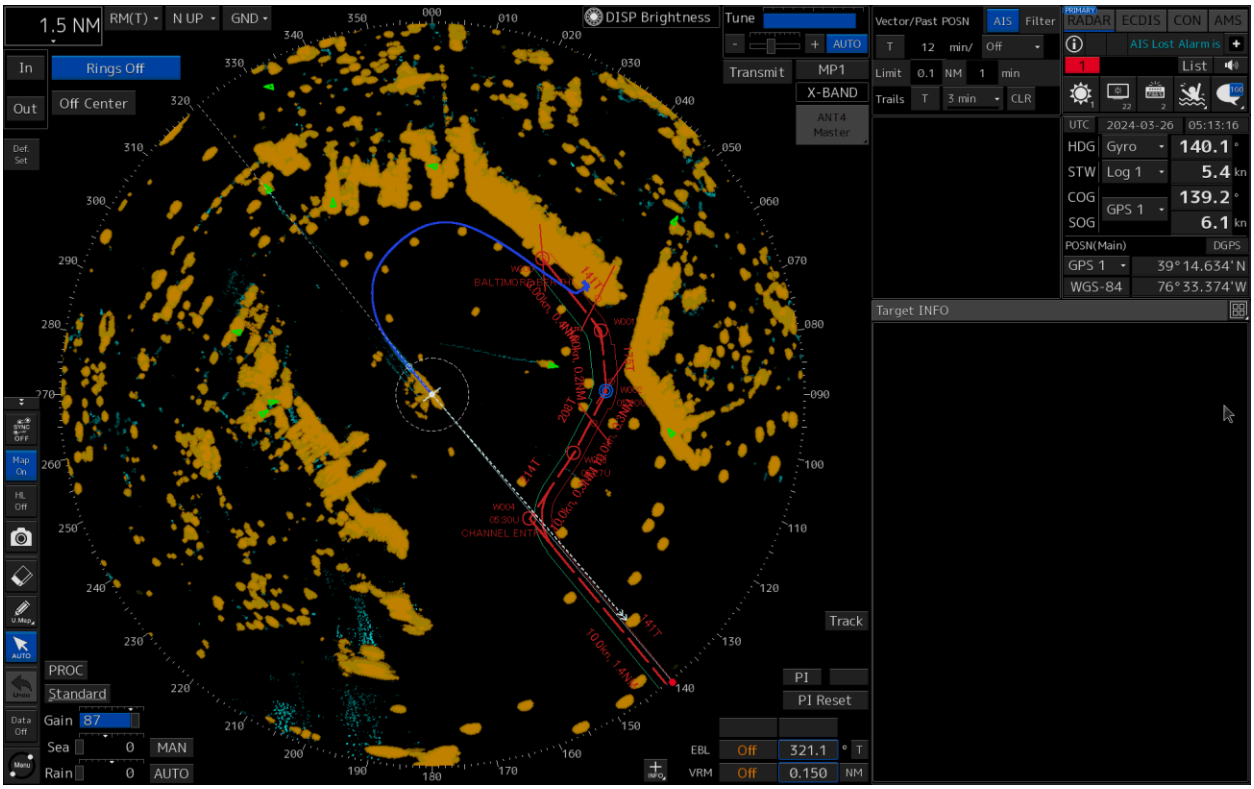

Figure 83. X-Band radar display at approximately 01:13:41 EDT.

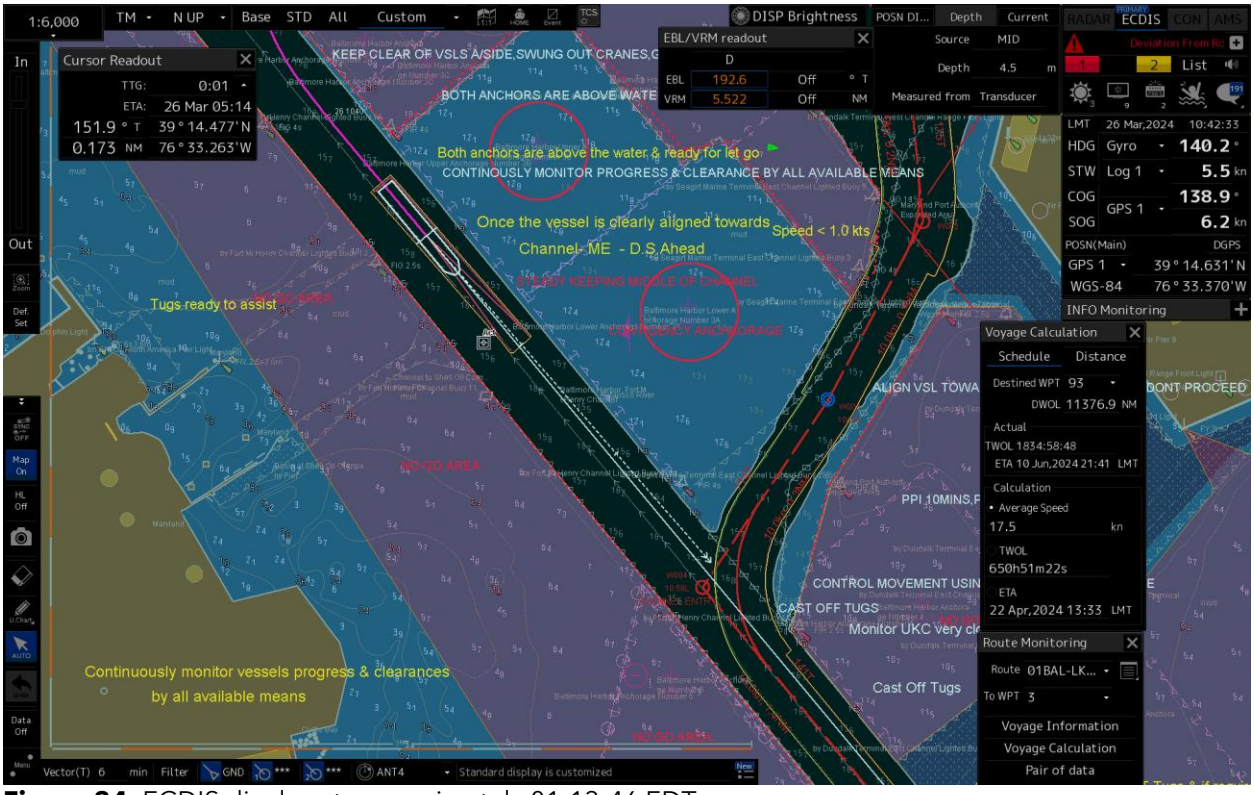

Figure 84. ECDIS display at approximately 01:13:46 EDT.

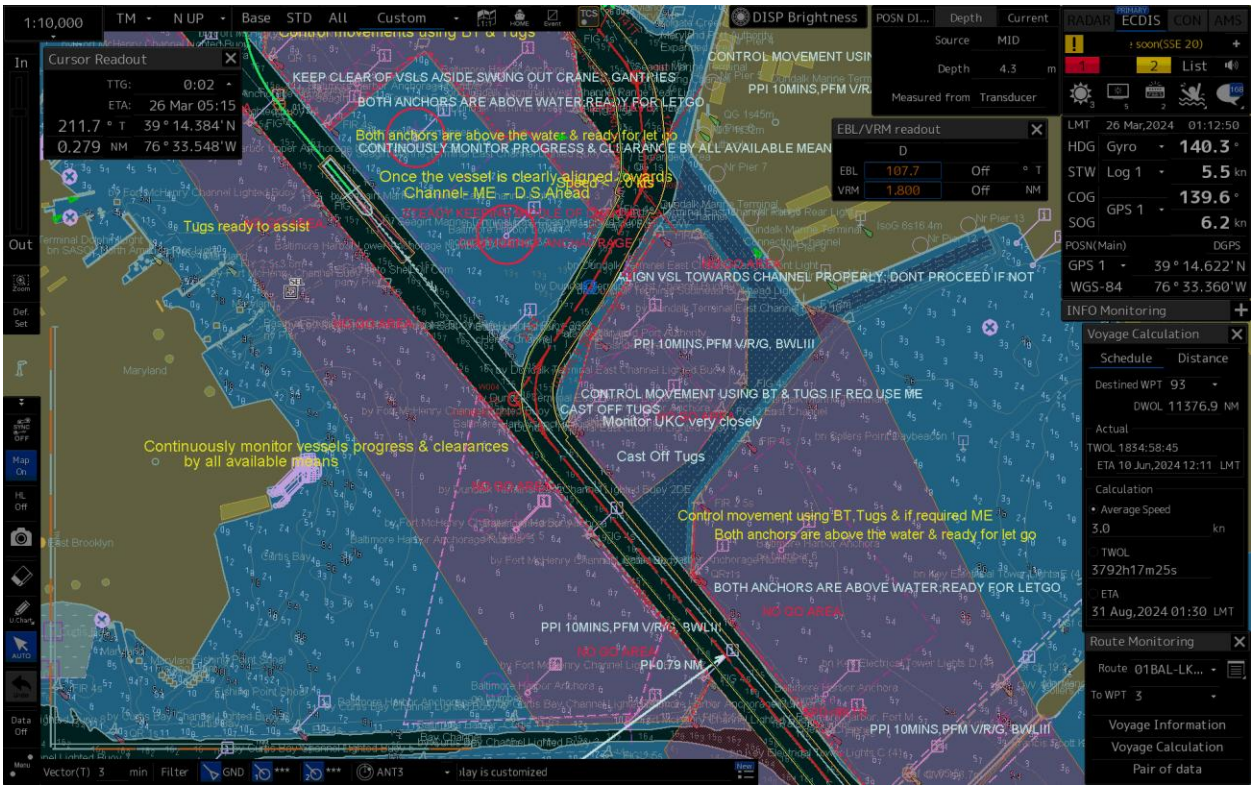

Figure 85. ECDIS display at approximately 01:13:51 EDT.

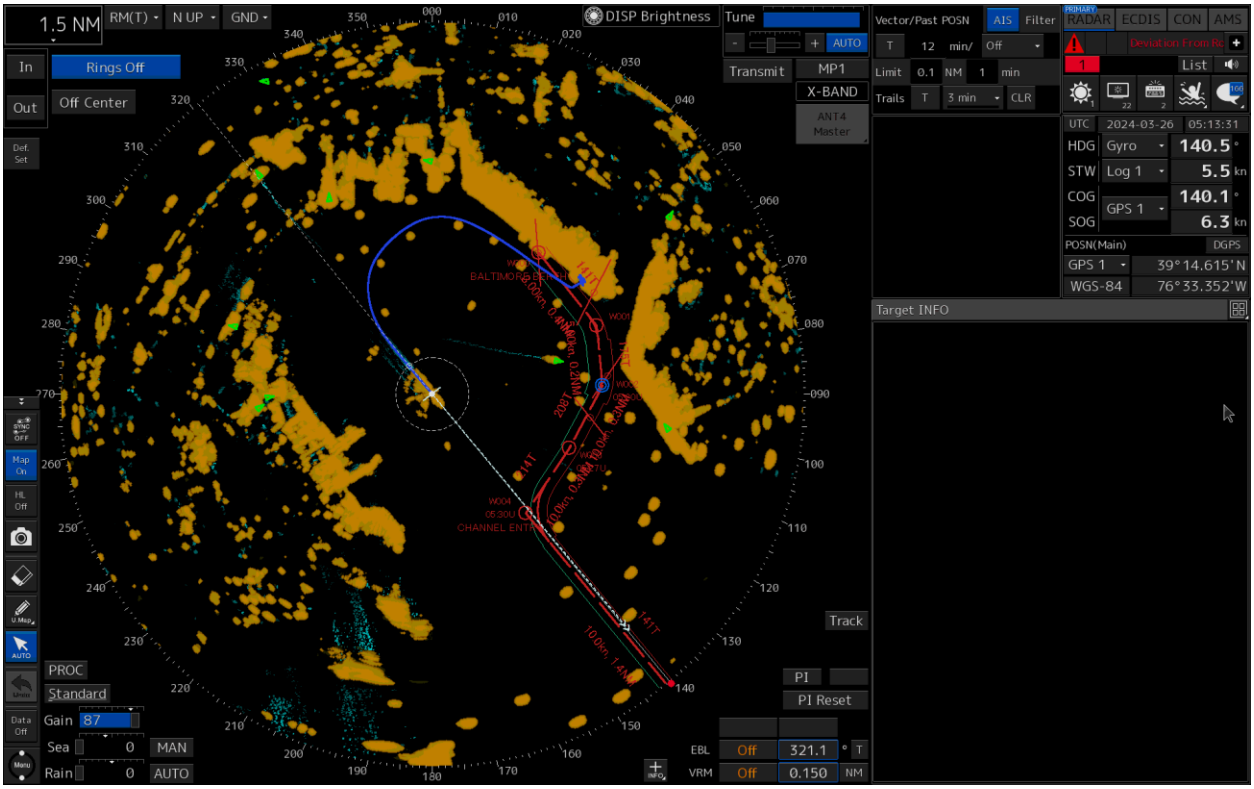

Figure 86. X-Band Radar display at approximately 01:13:56 EDT.

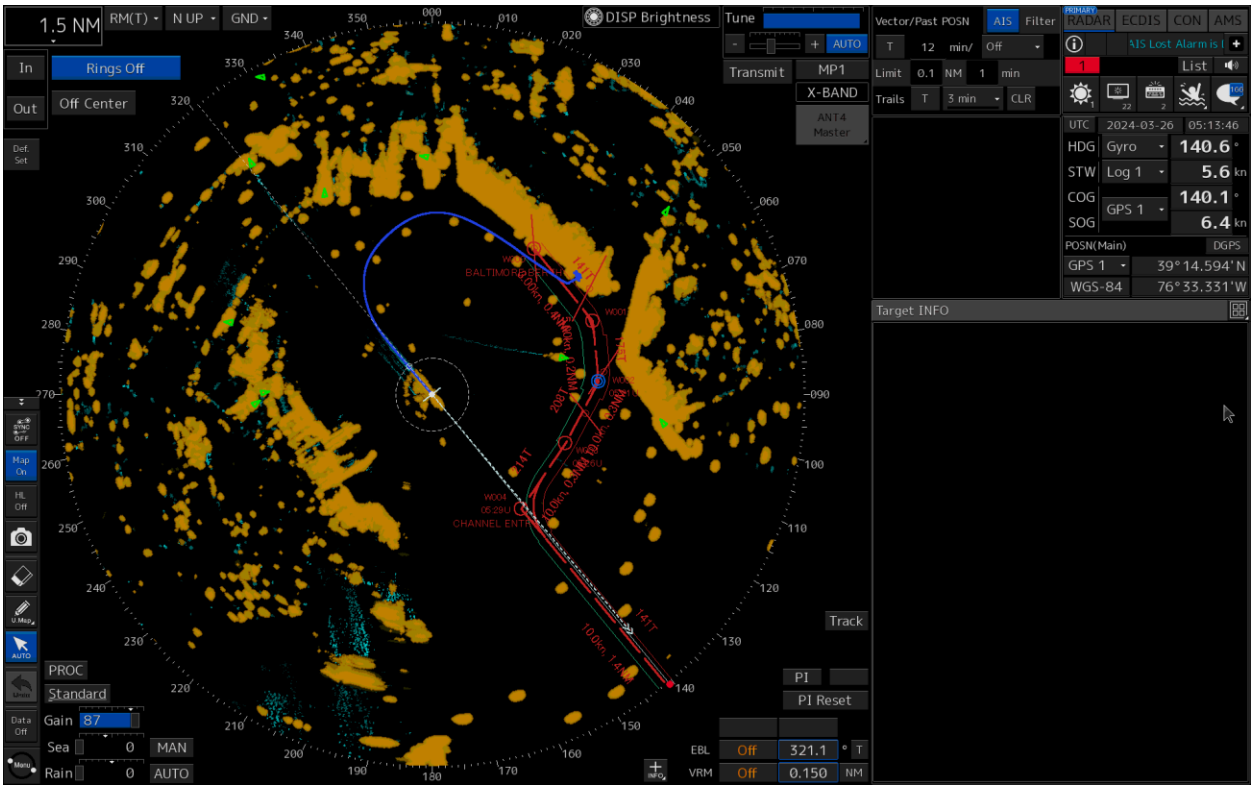

Figure 87. X-Band Radar display at approximately 01:14:11 EDT.

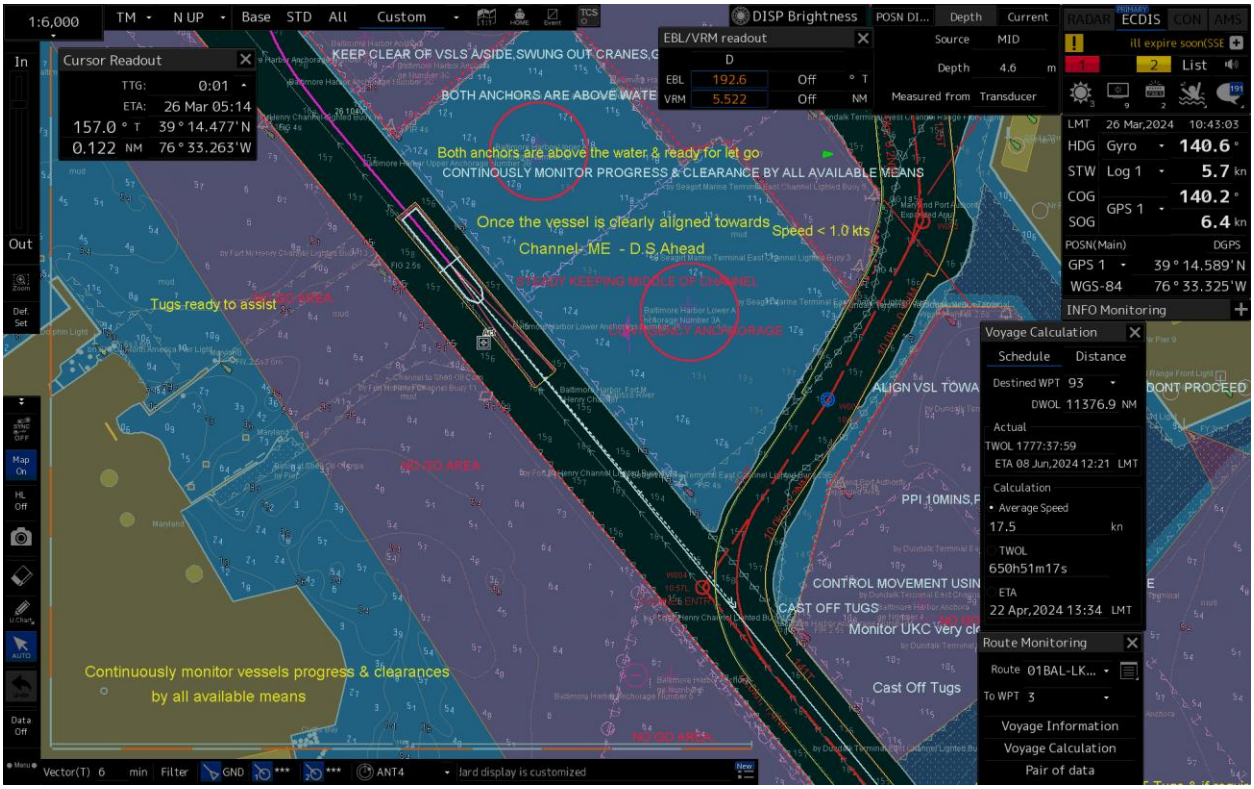

Figure 88. ECDIS display at approximately 01:14:16 EDT.

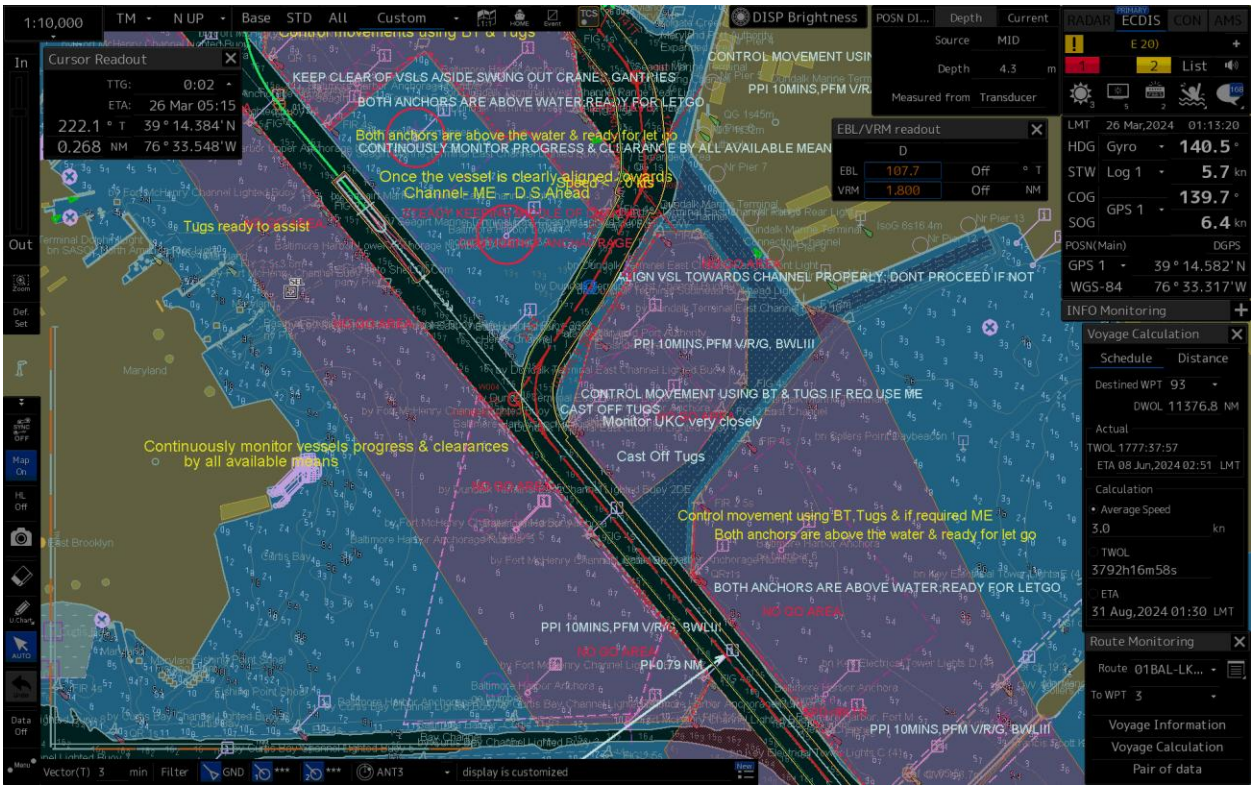

Figure 89. ECDIS display at approximately 01:14:21 EDT.

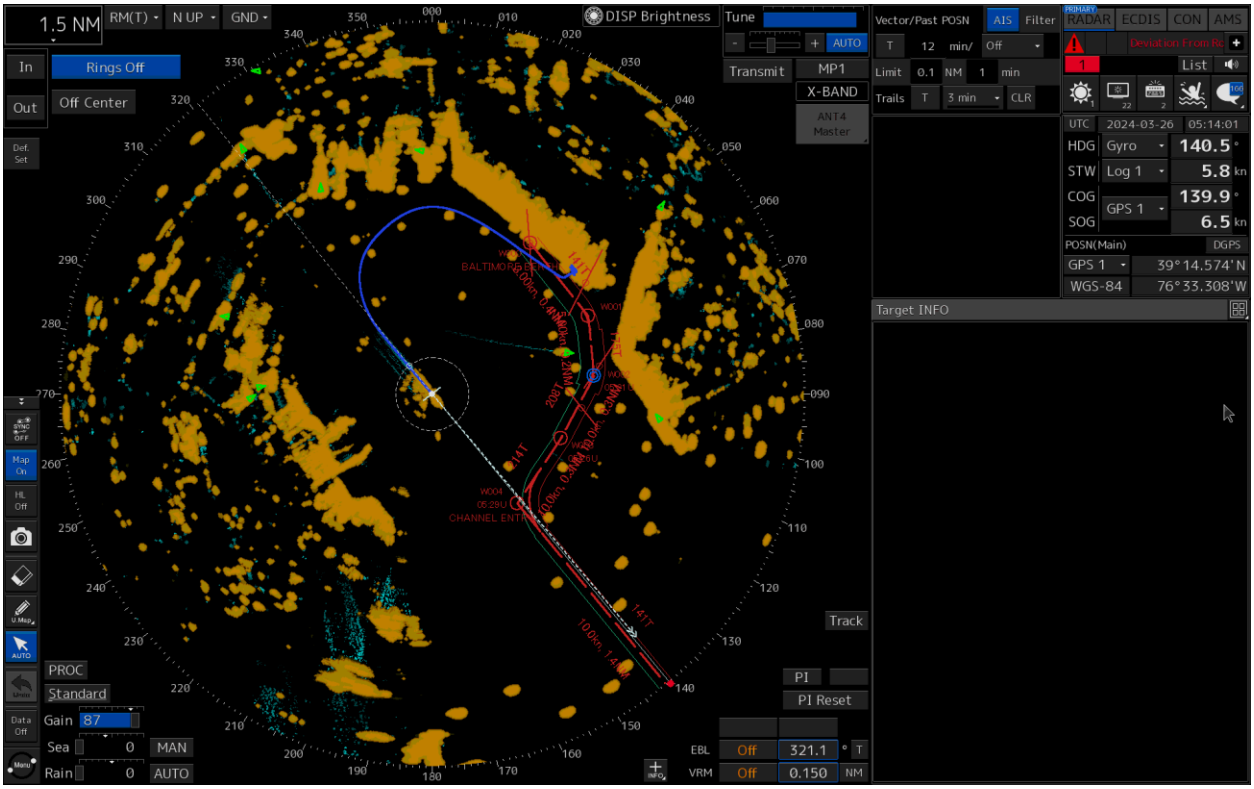

Figure 90. X-Band radar display at approximately 01:14:26 EDT.

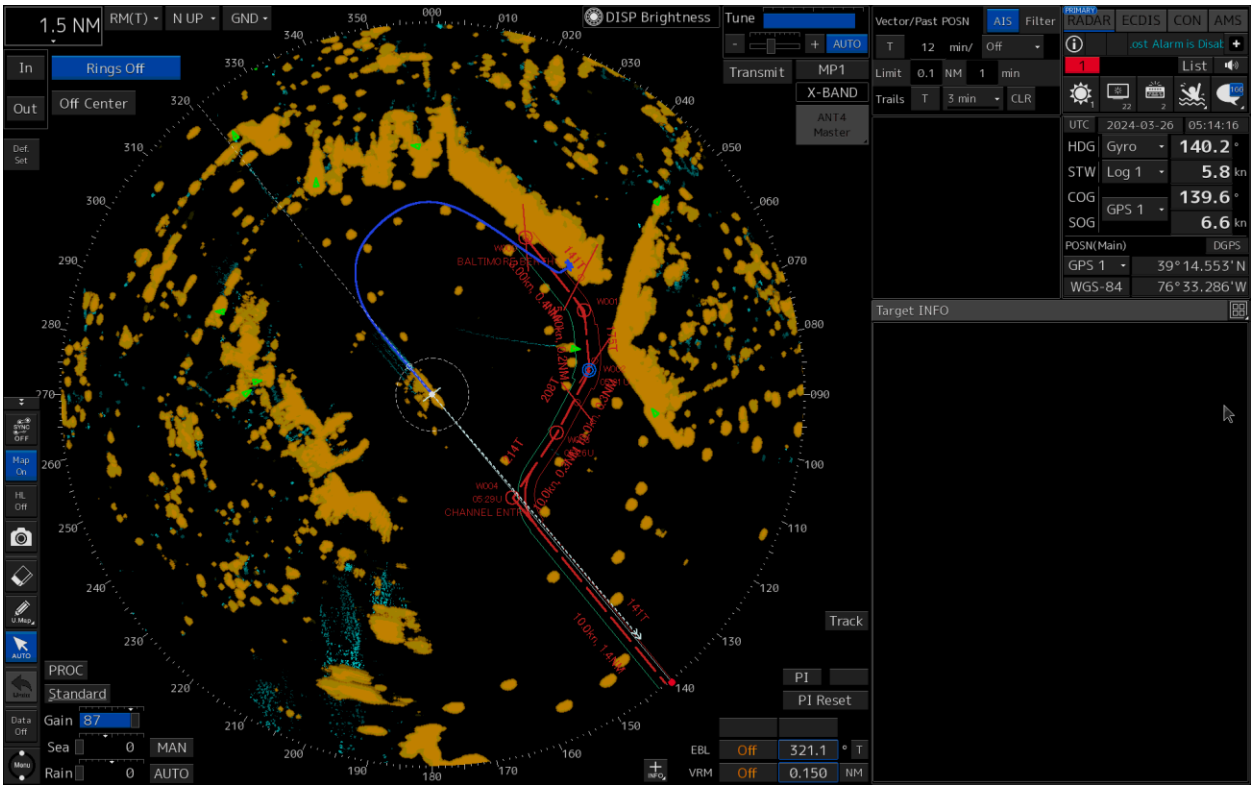

Figure 91. X-Band radar display at approximately 01:14:41 EDT.

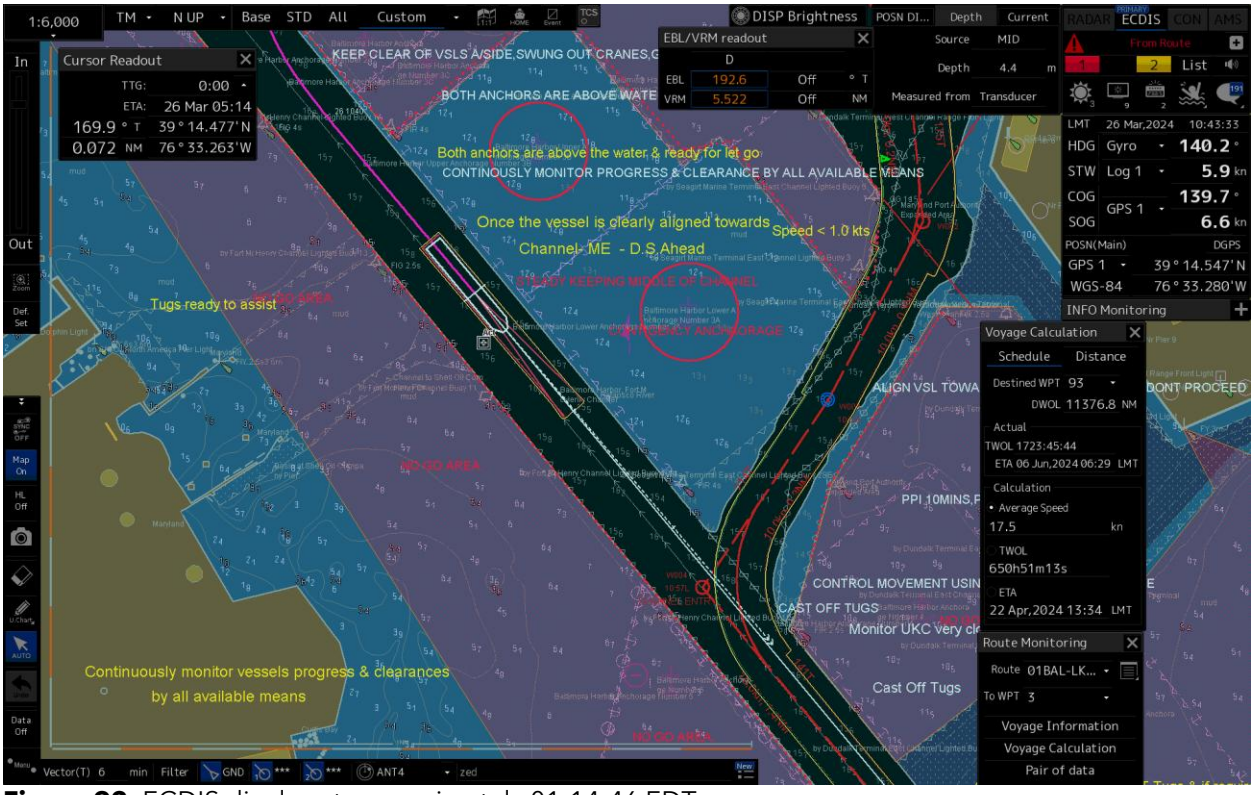

Figure 92. ECDIS display at approximately 01:14:46 EDT.

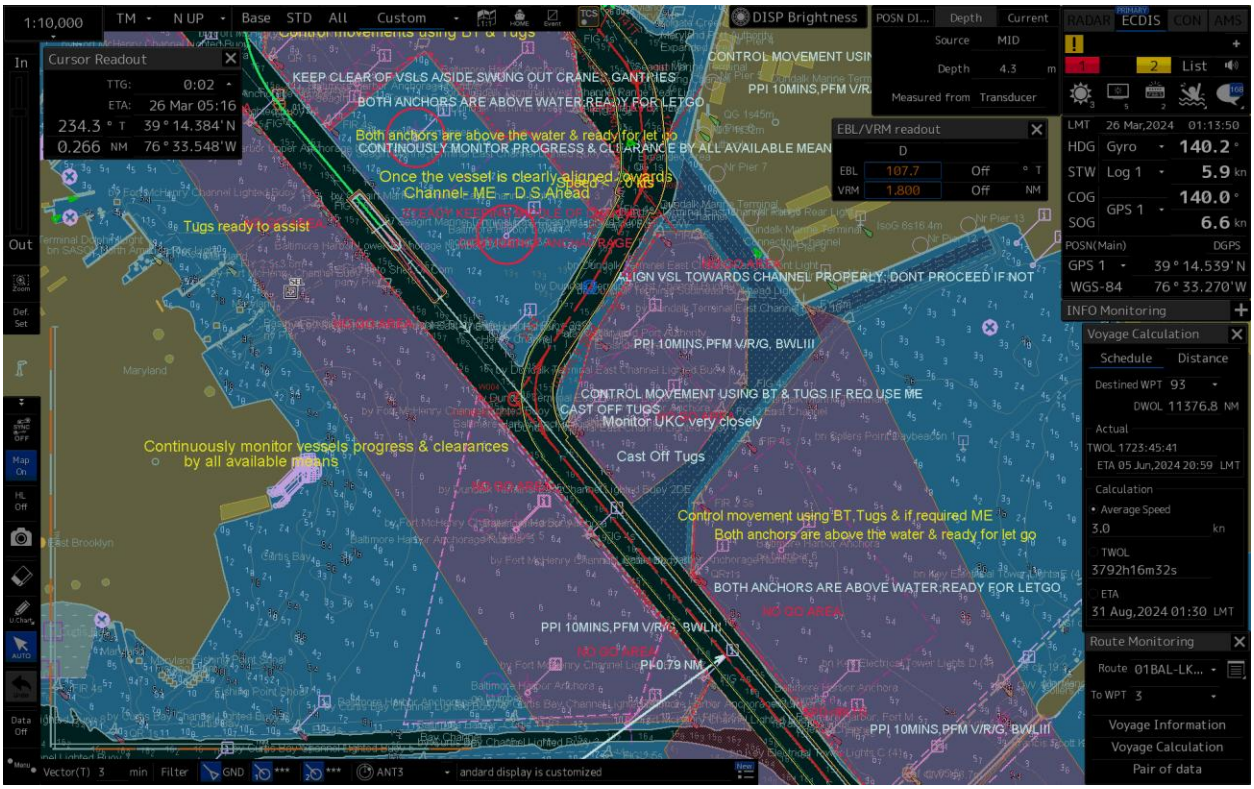

Figure 93. ECDIS display at approximately 01:14:51 EDT.

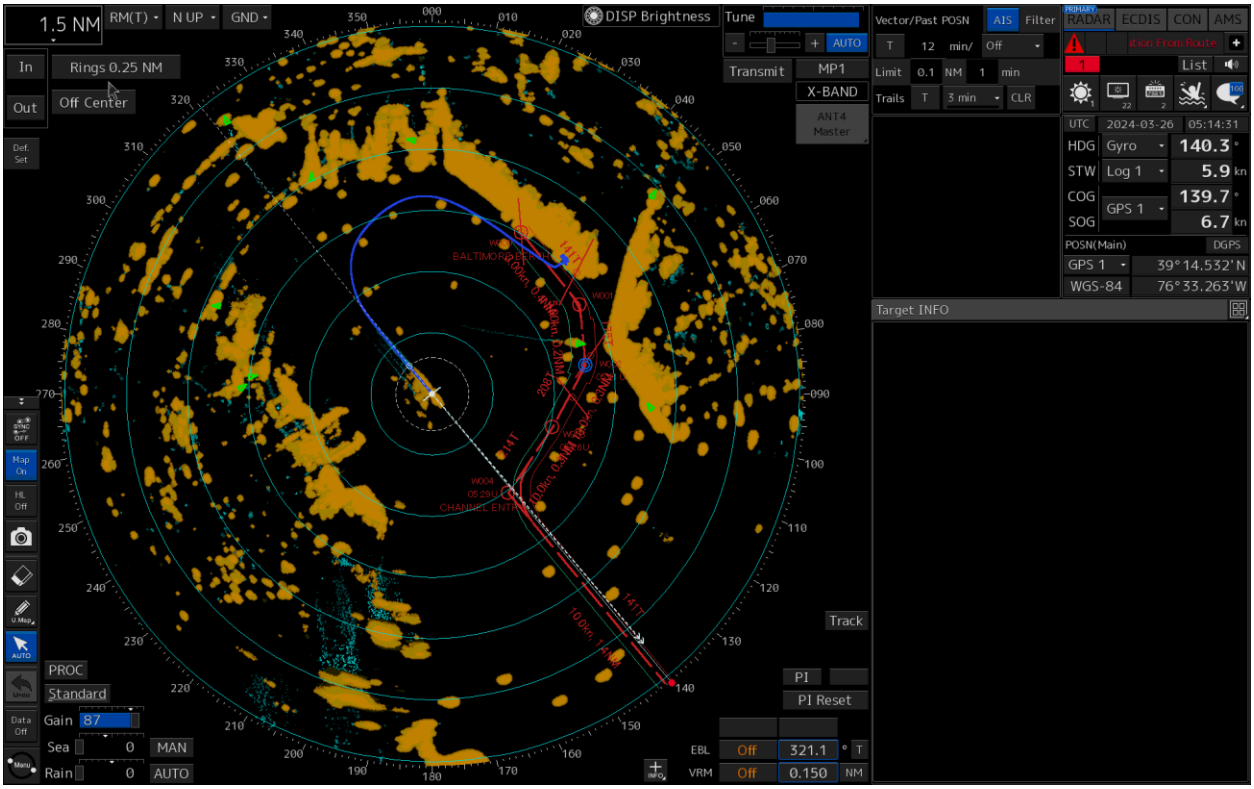

Figure 94. X-Band radar display at approximately 01:14:56 EDT.

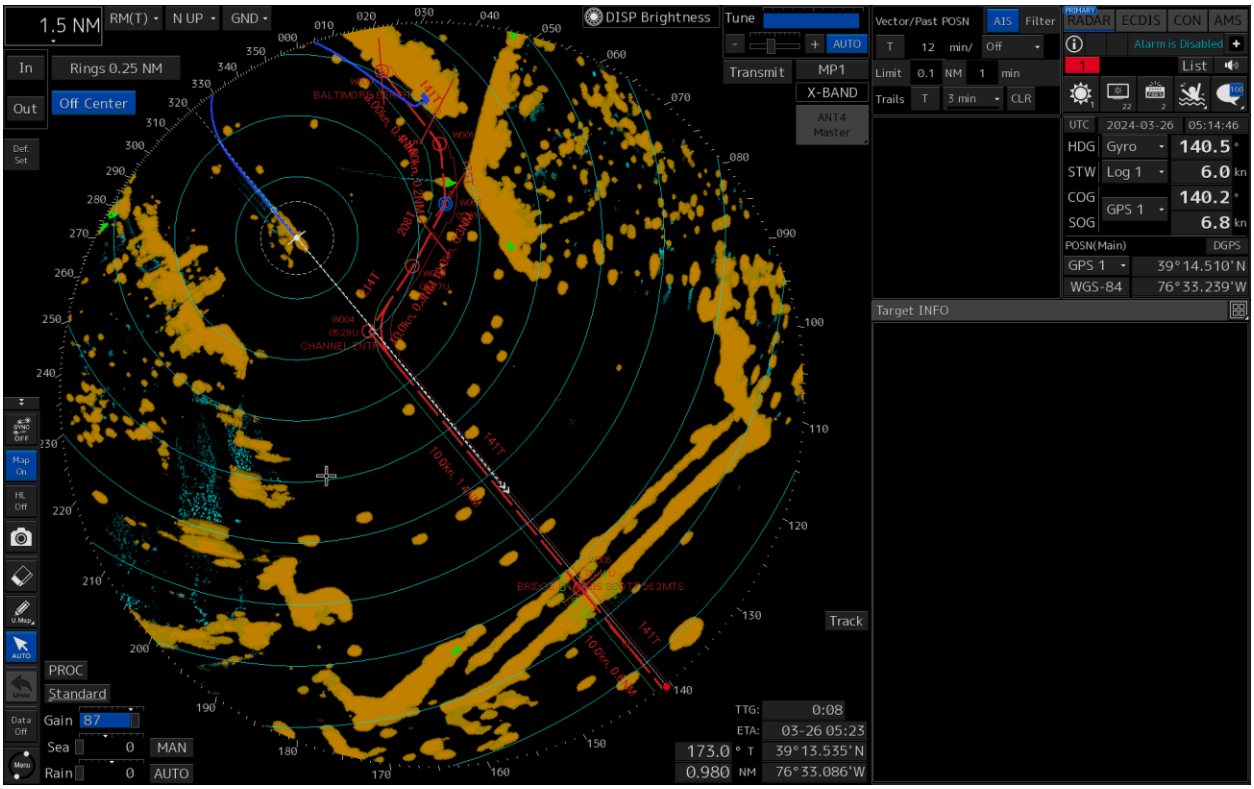

Figure 95. X-Band radar display at approximately 01:15:11 EDT.

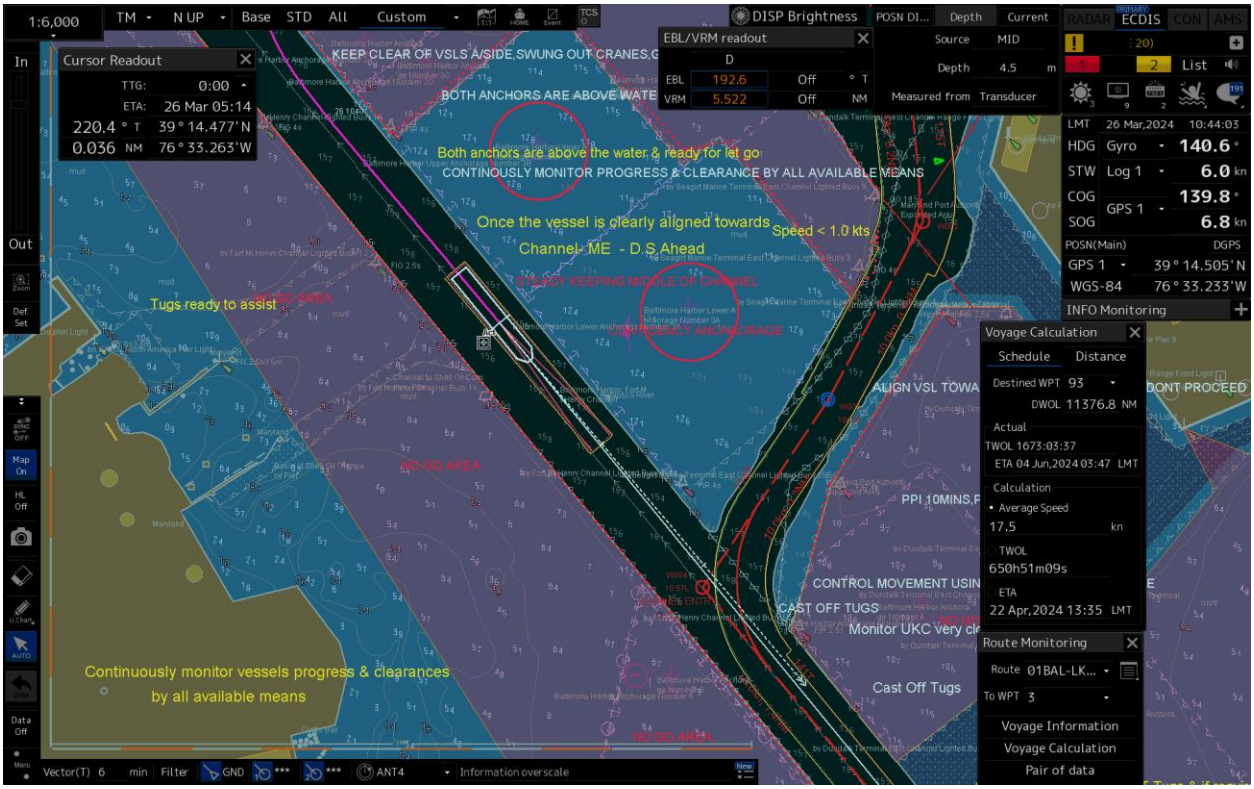

Figure 96. ECDIS display at approximately 01:15:16 EDT.

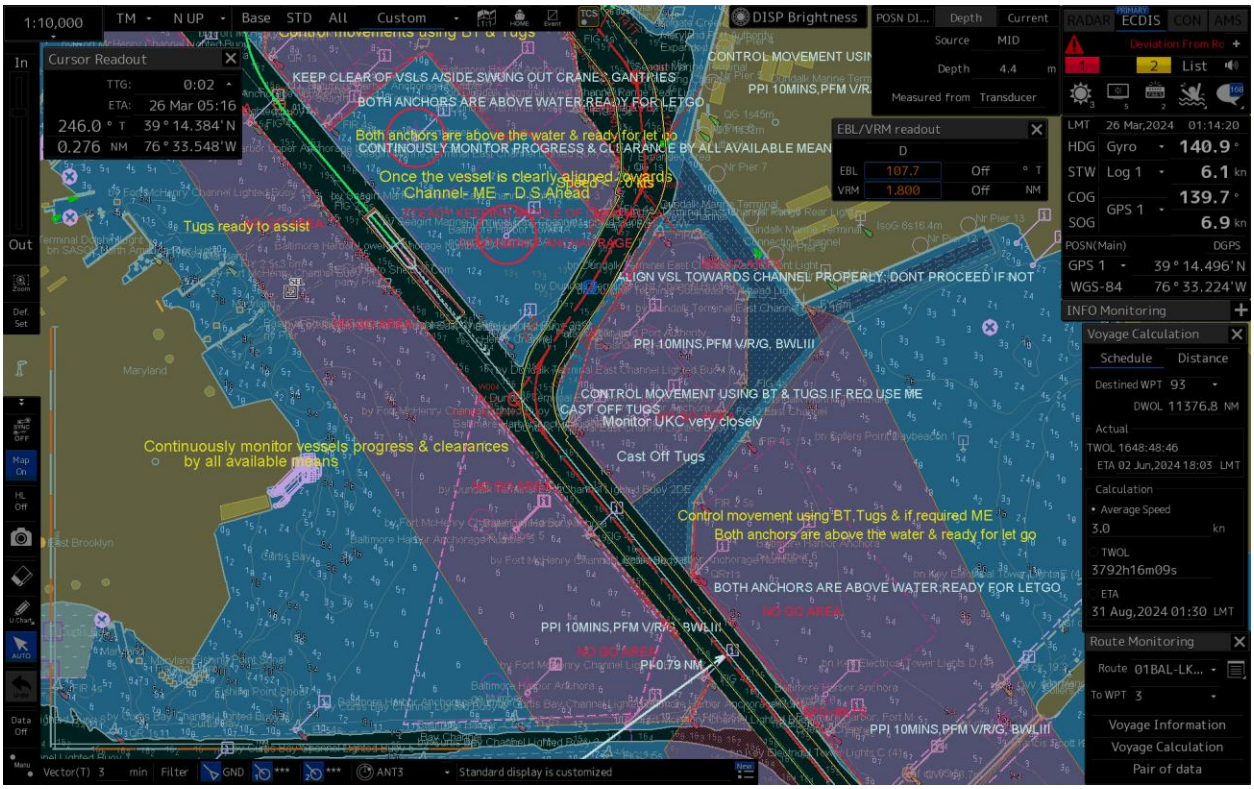

Figure 97. ECDIS display at approximately 01:15:21 EDT.

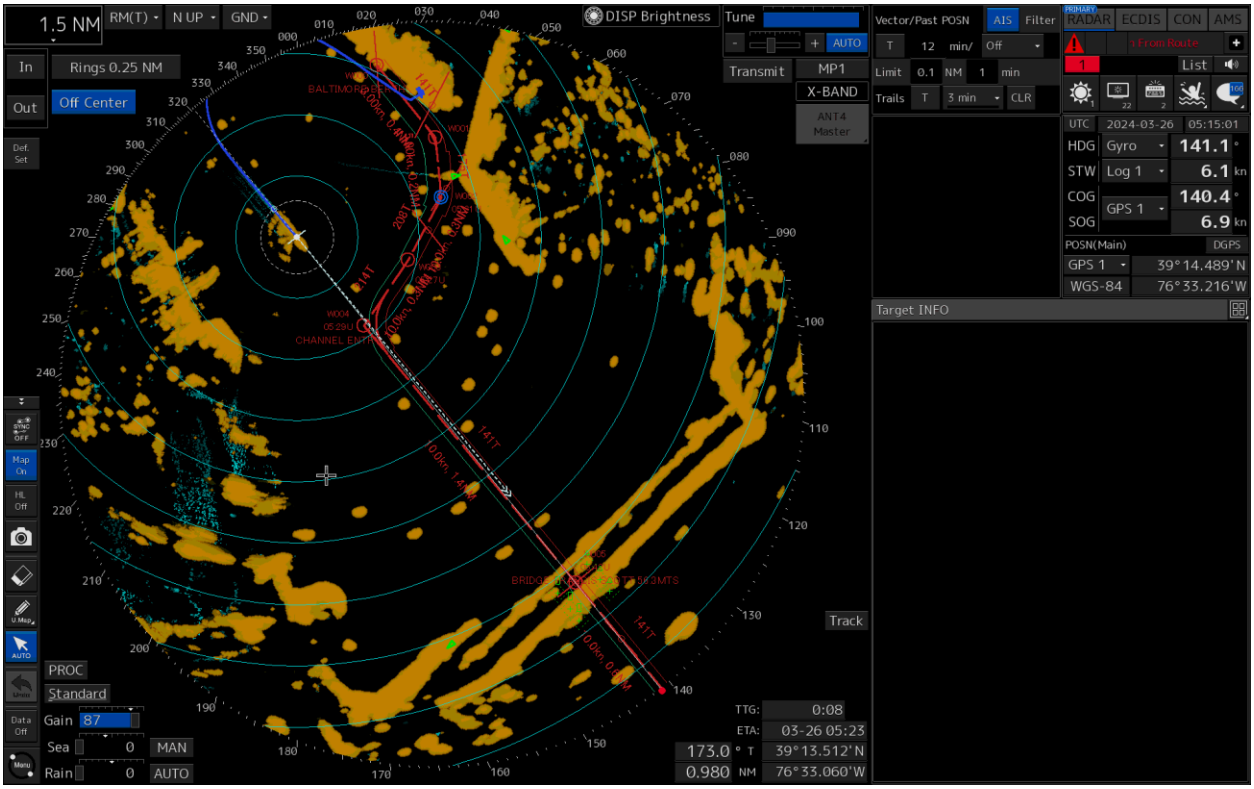

Figure 98. X-Band radar display at approximately 01:15:26 EDT.

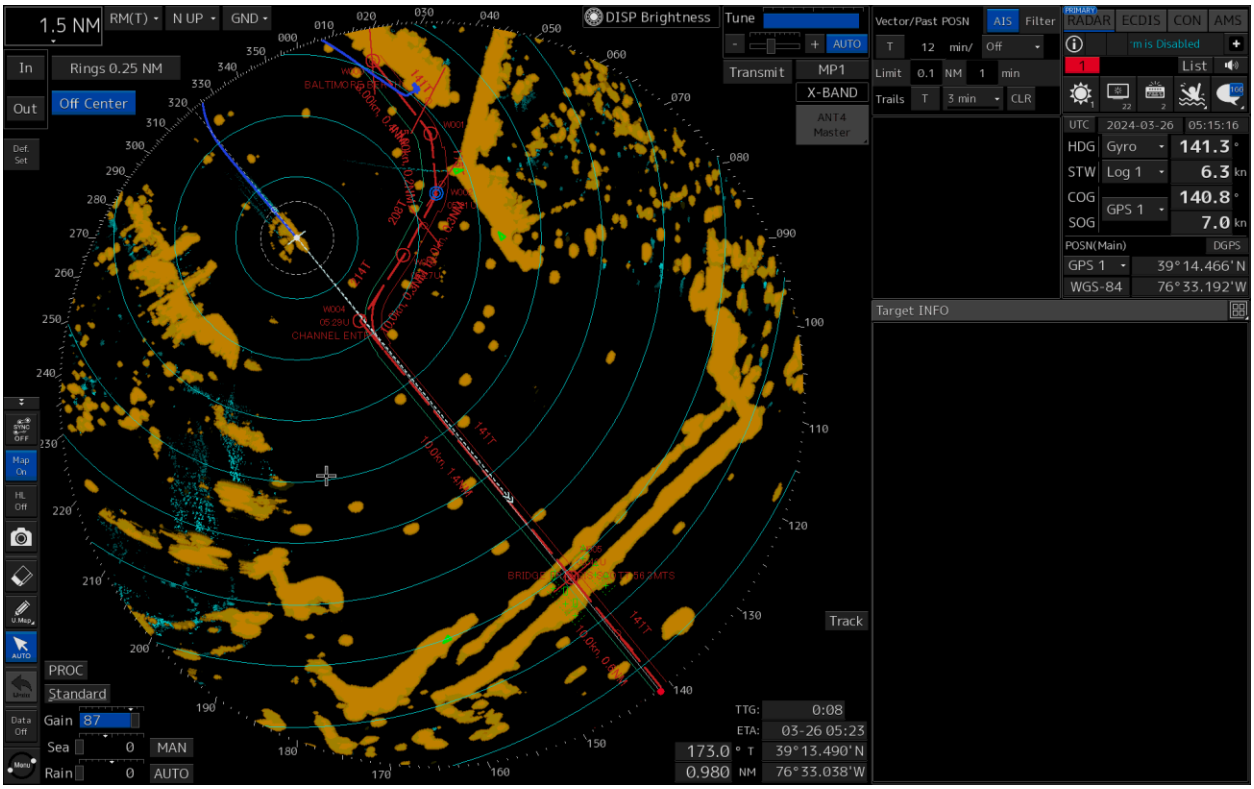

Figure 99. X-Band radar display at approximately 01:15:41 EDT.

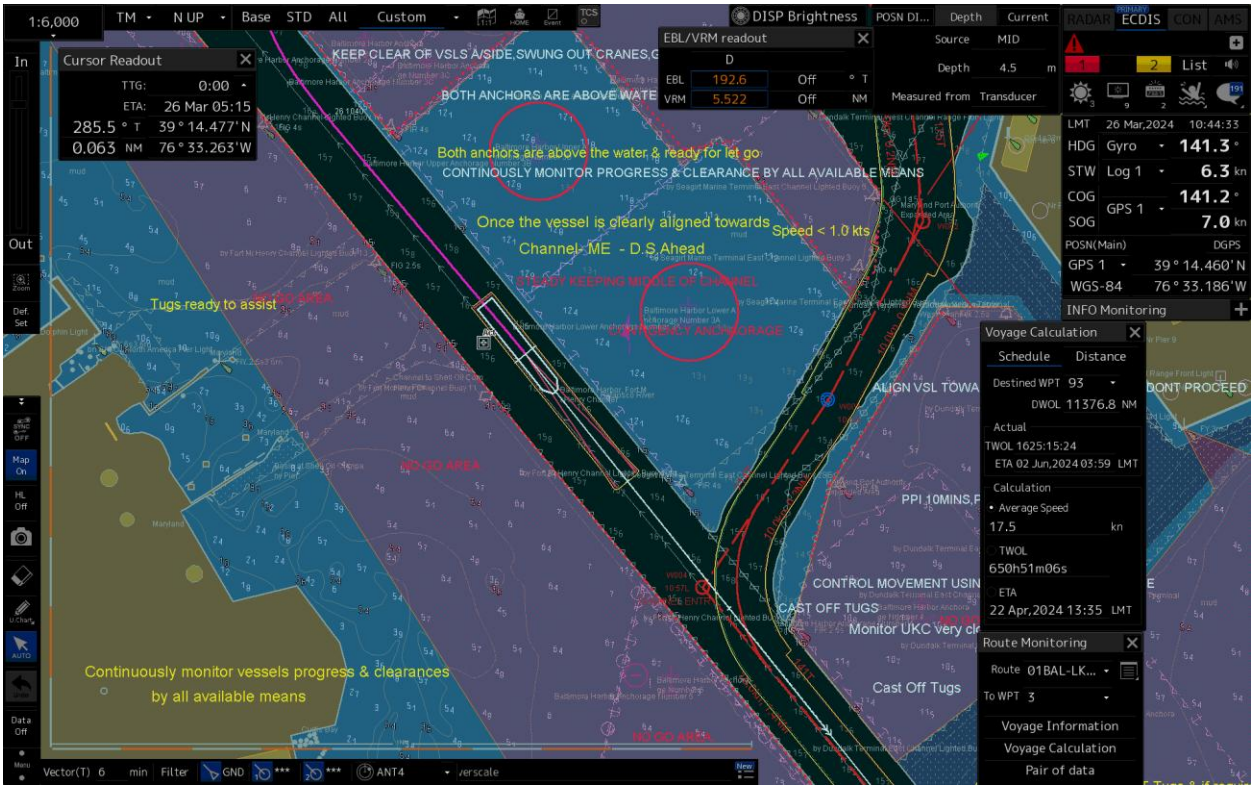

Figure 100. ECDIS display at approximately 01:15:46 EDT.

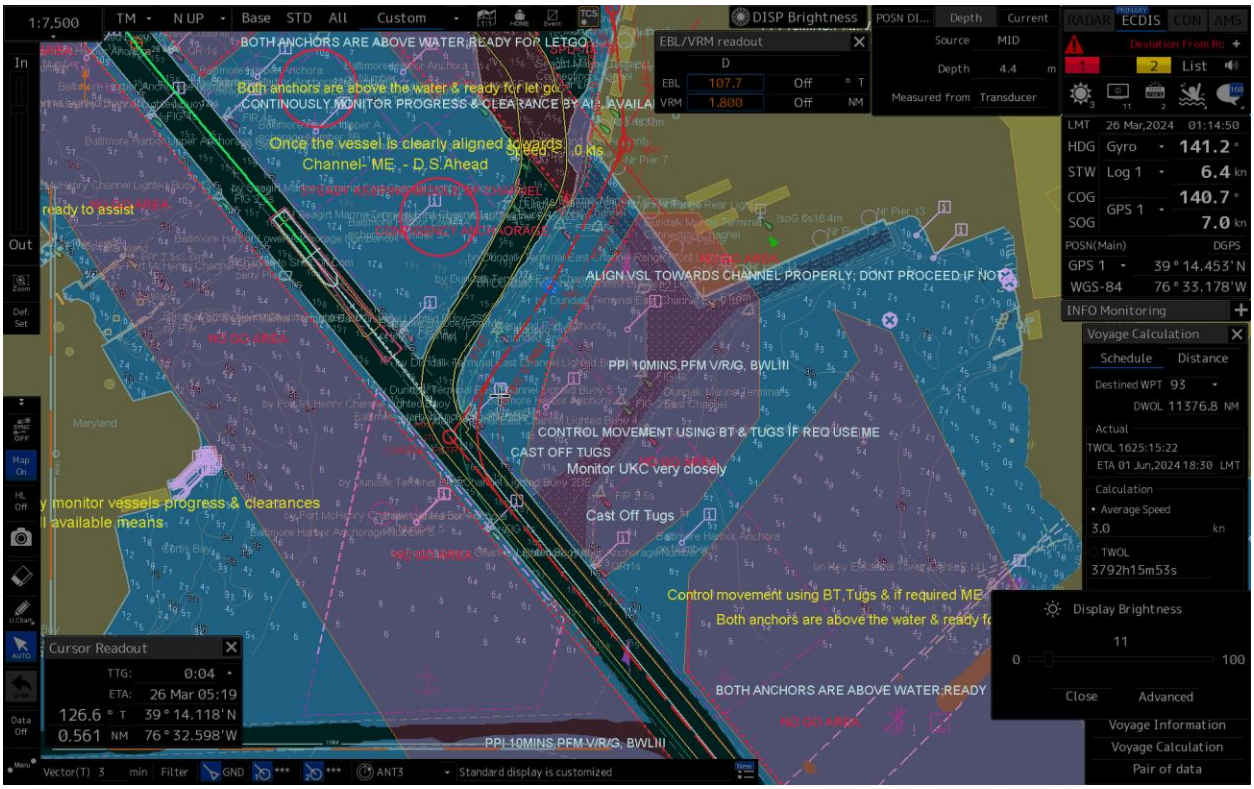

Figure 101. ECDIS display at approximately 01:15:51 EDT.

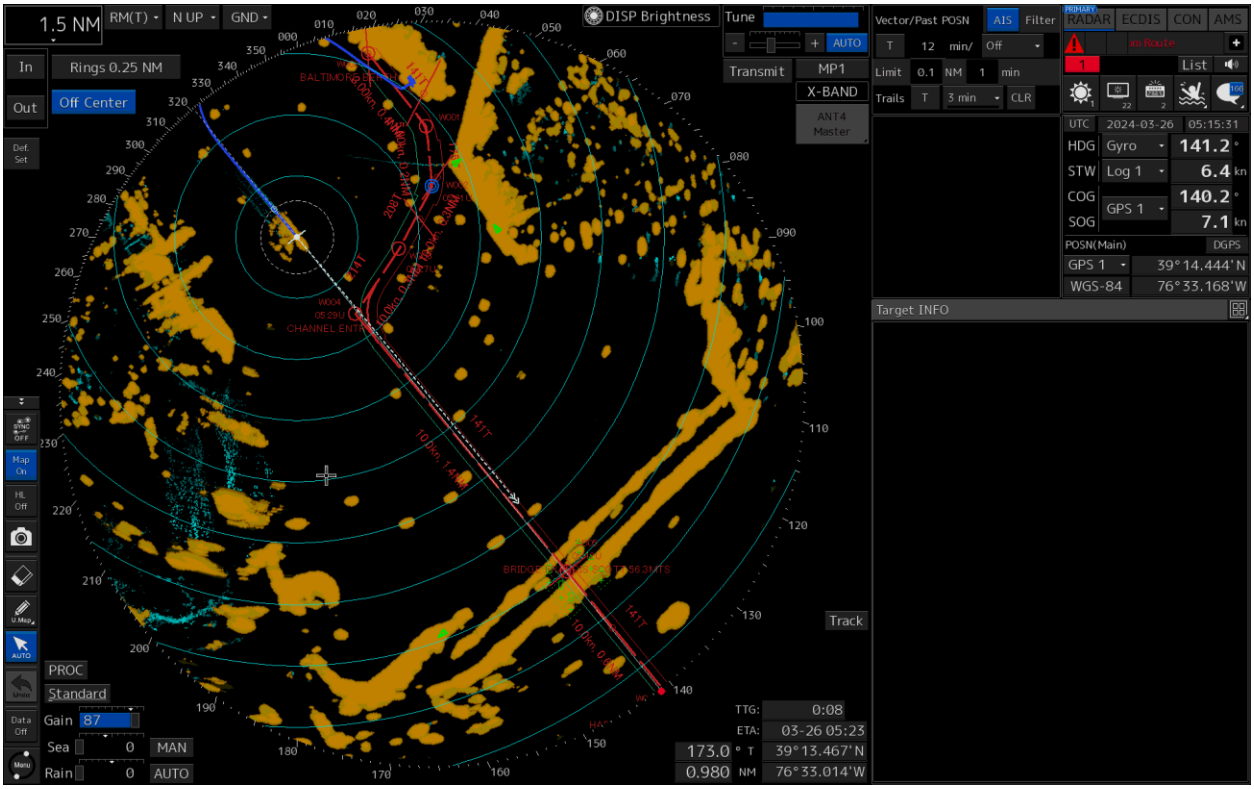

Figure 102. X-Band radar display at approximately 01:15:56 EDT.

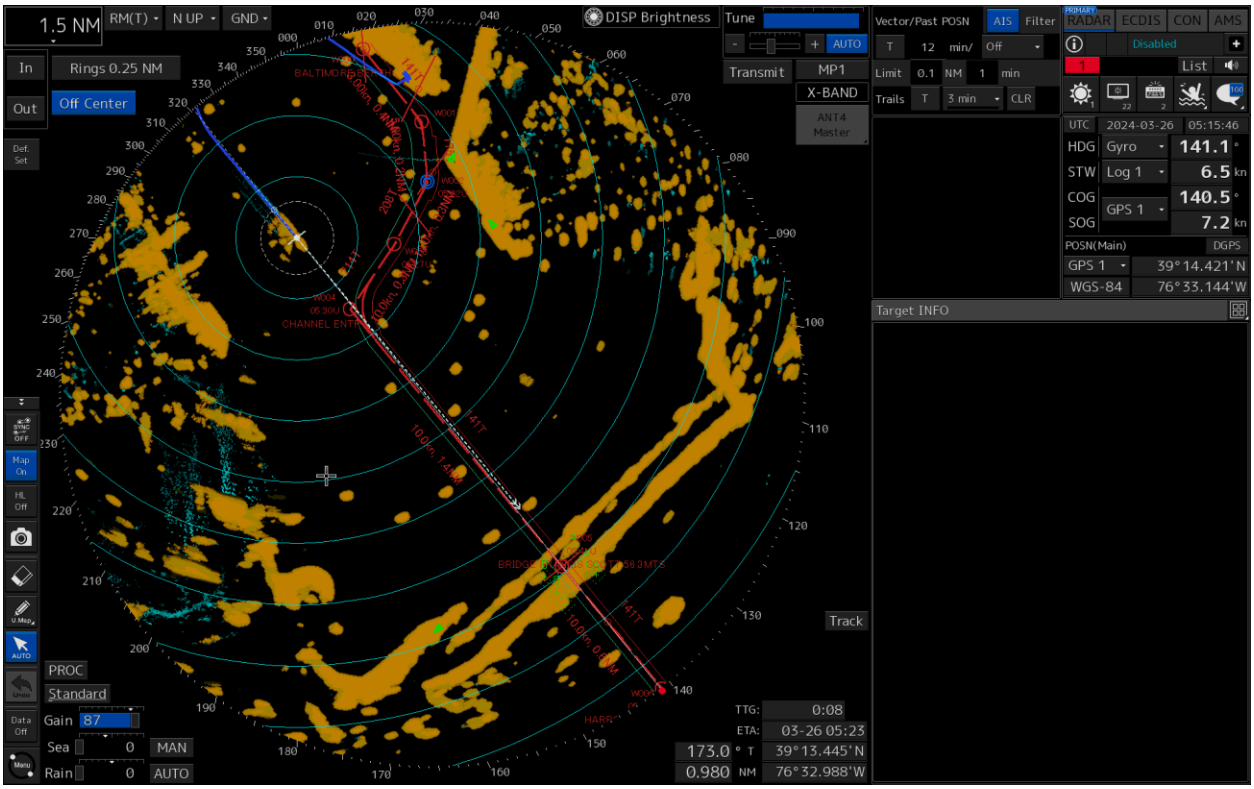

Figure 103. X-Band radar display at approximately 01:16:11 EDT.

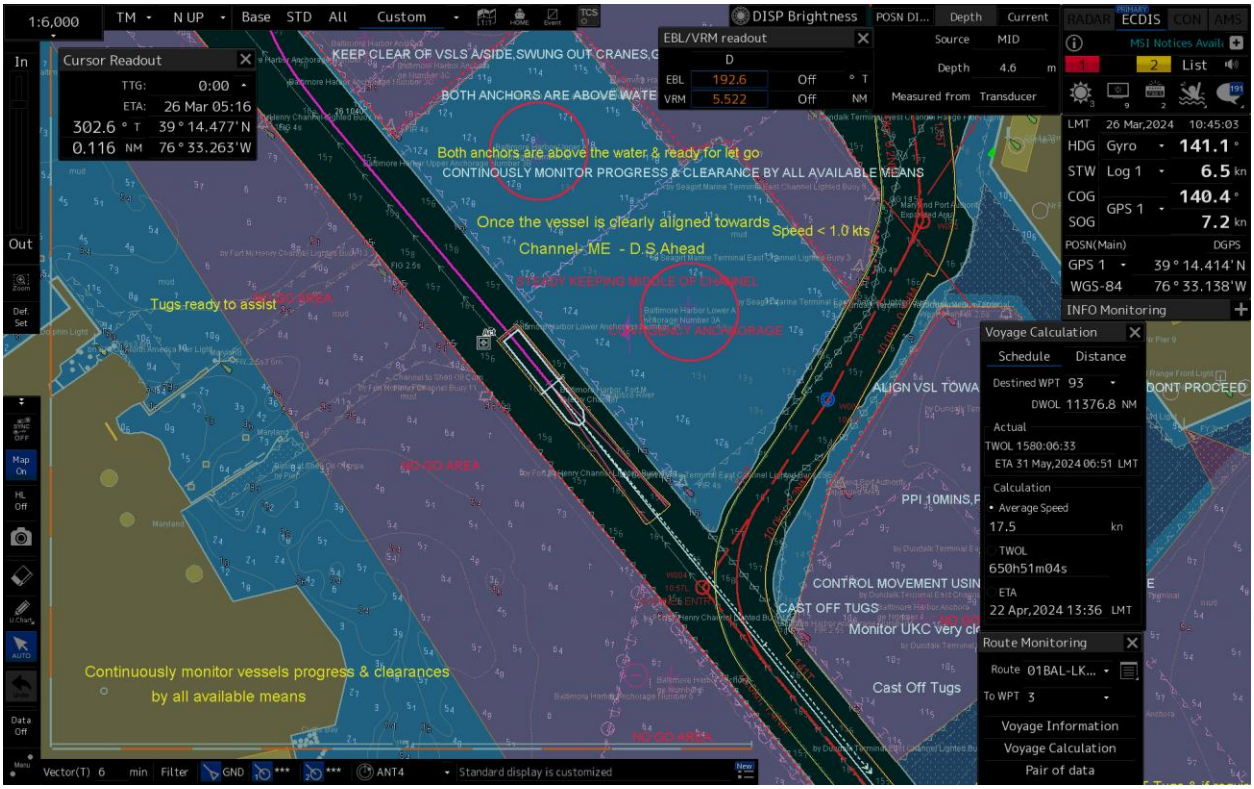

Figure 104. ECDIS display at approximately 01:16:16 EDT.

Figure 105. ECDIS display at approximately 01:16:21 EDT.

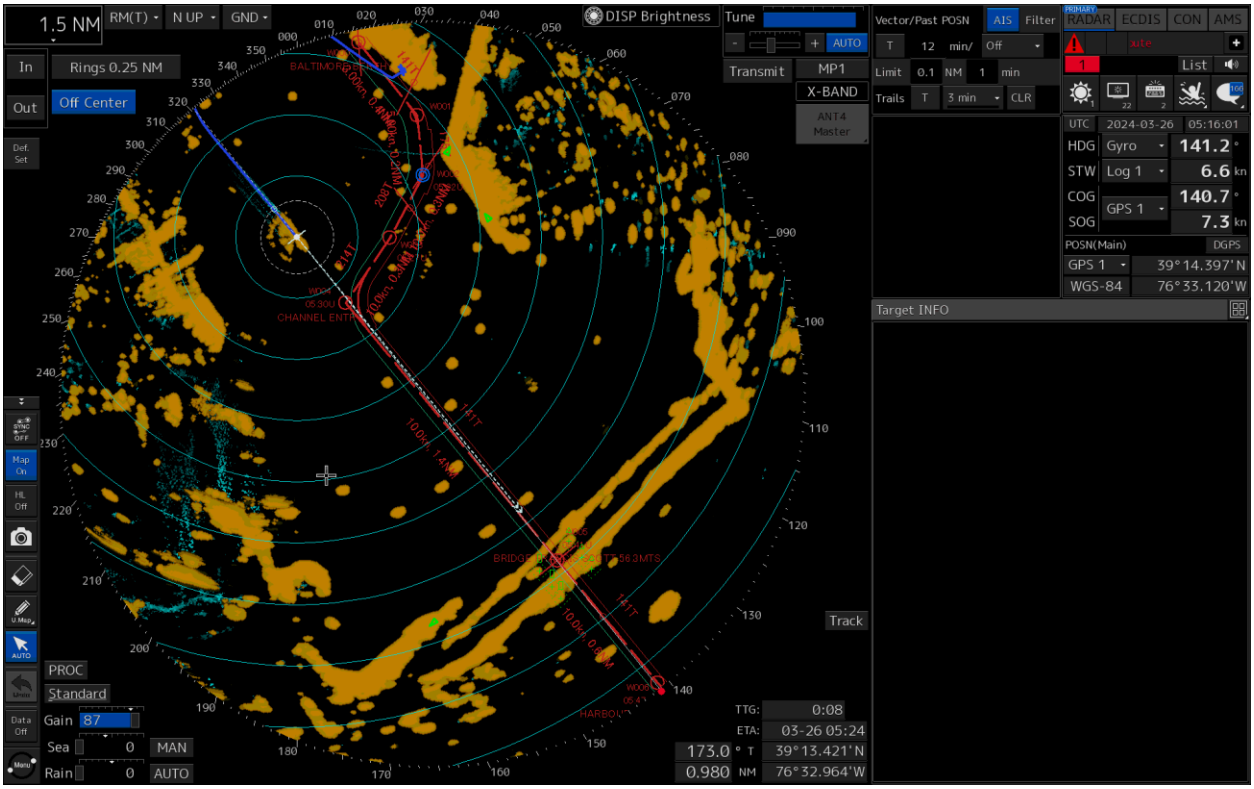

Figure 106. X-Band radar display at approximately 01:16:26 EDT.

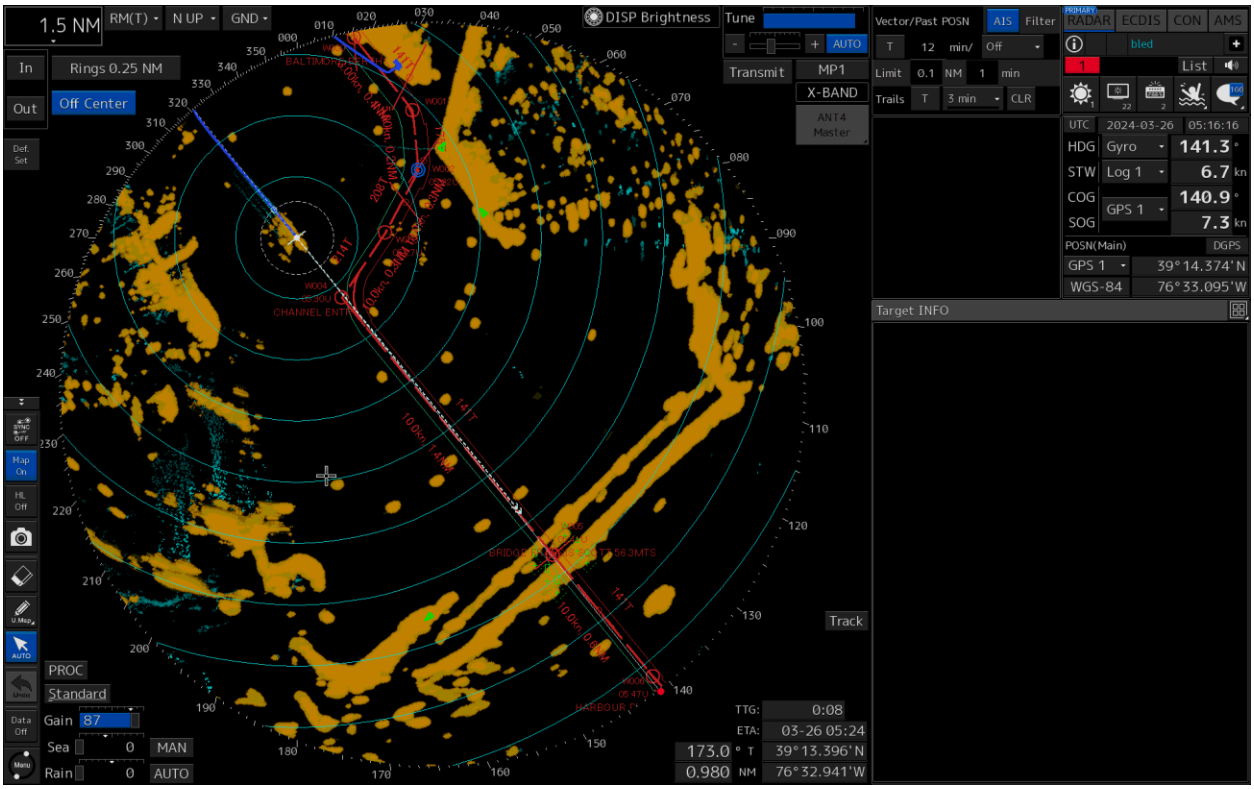

Figure 107. X-Band radar display at approximately 01:16:41 EDT.

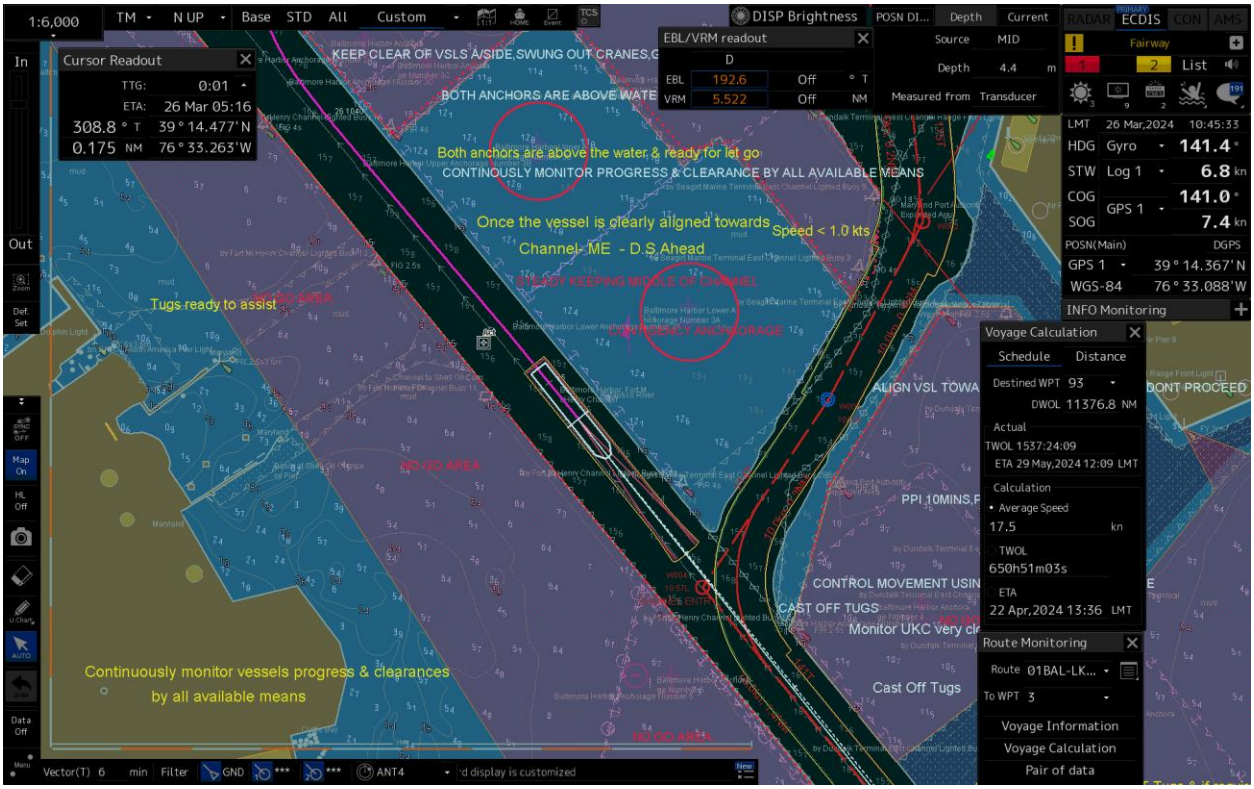

Figure 108. ECDIS display at approximately 01:16:46 EDT.

Figure 109. ECDIS display at approximately 01:16:51 EDT.

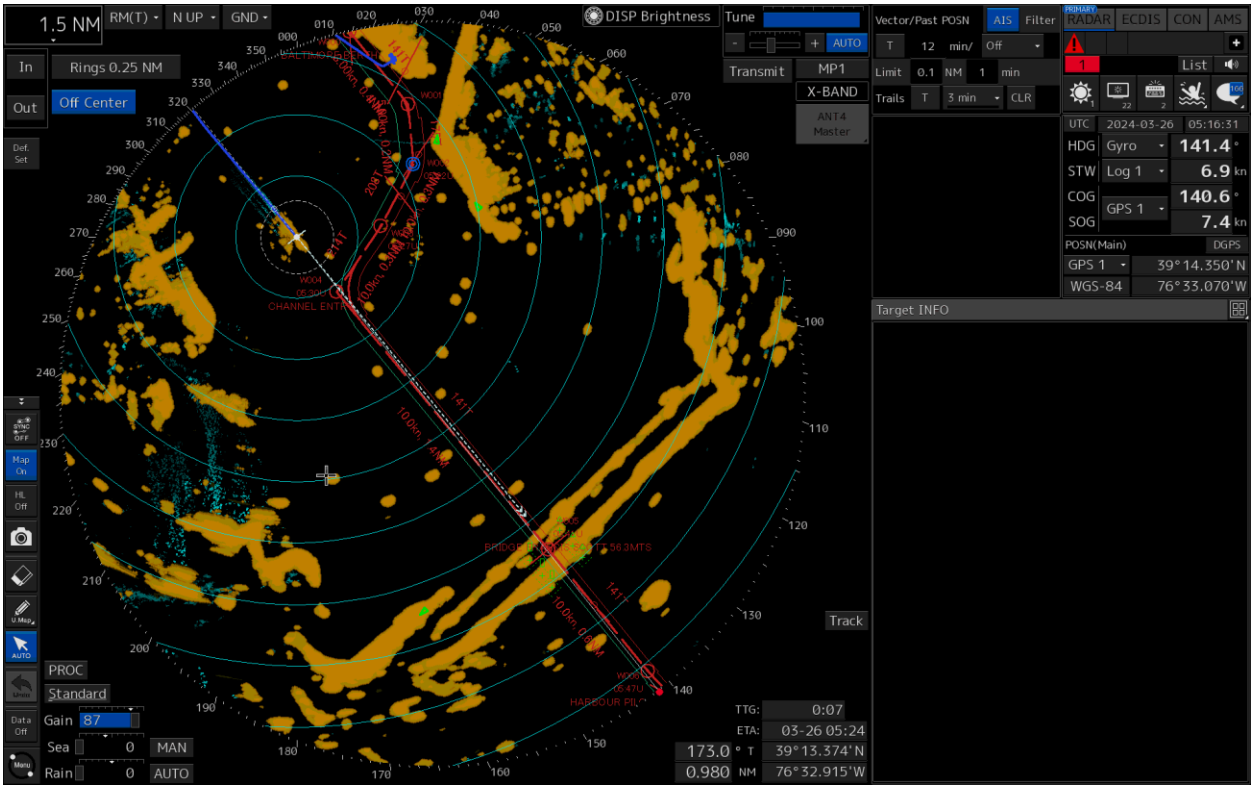

Figure 110. X-Band radar display at approximately 01:16:56 EDT.

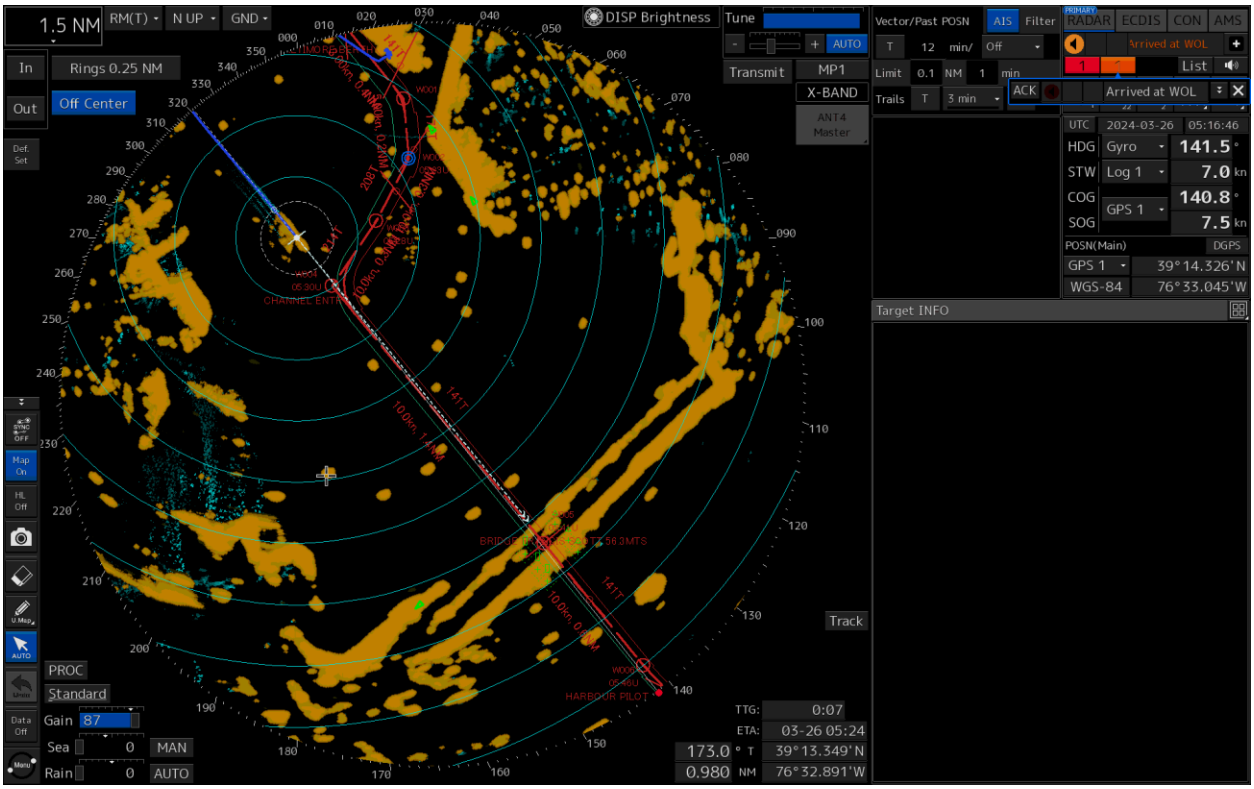

Figure 111. X-Band radar display at approximately 01:17:11 EDT.

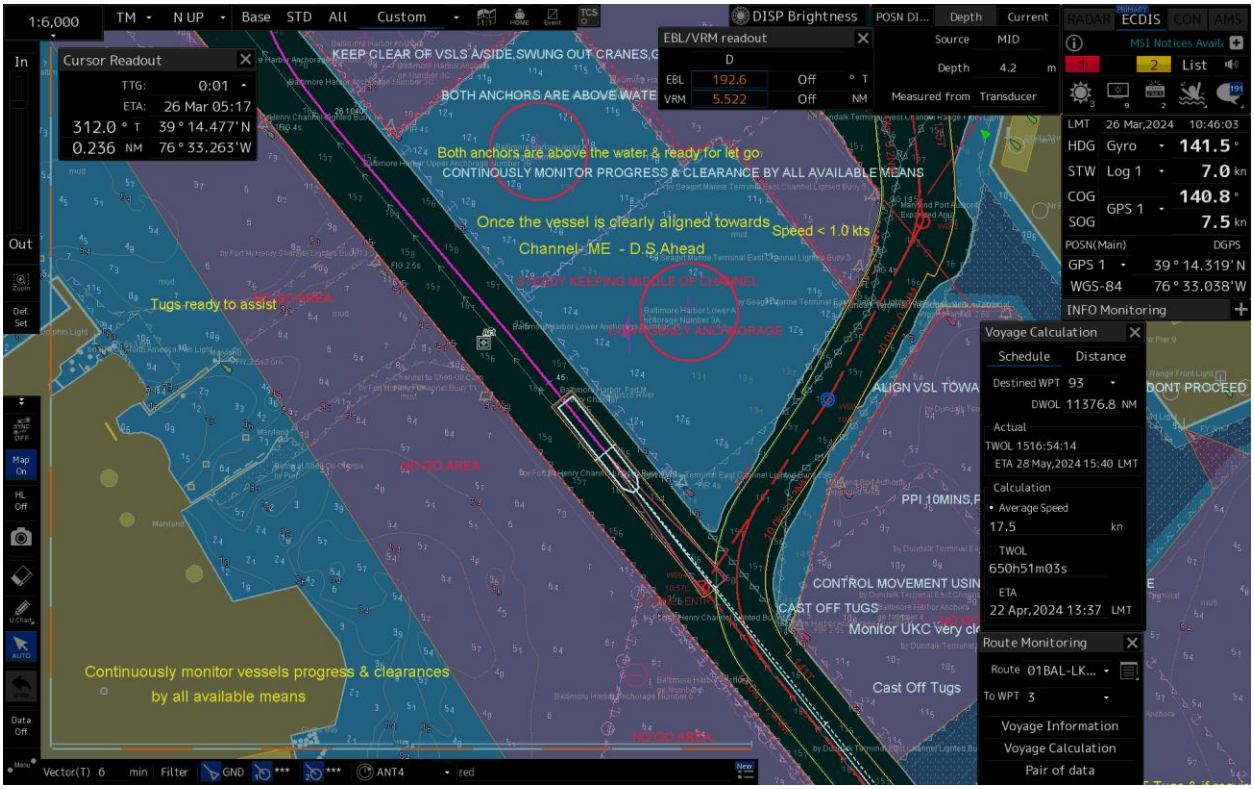

Figure 112. ECDIS display at approximately 01:17:16 EDT.

Figure 113. ECDIS display at approximately 01:17:21 EDT.

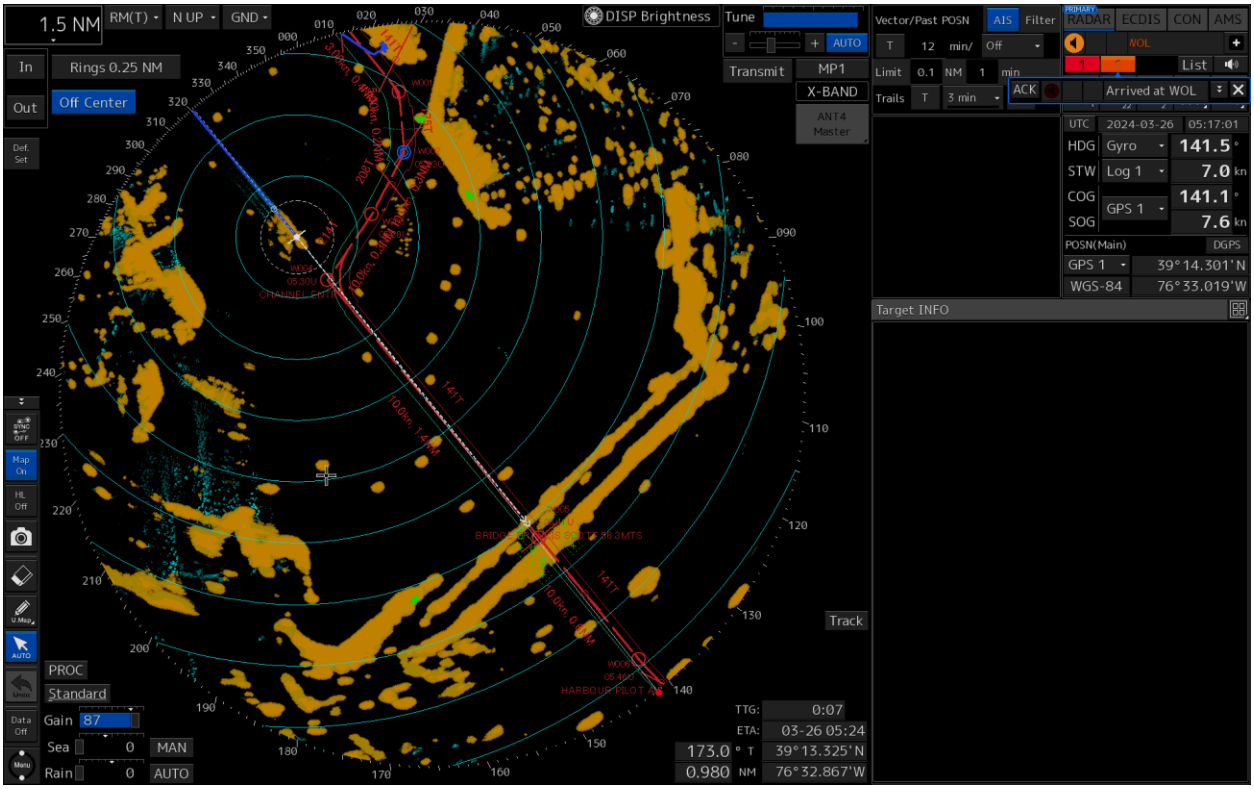

Figure 114. X-Band radar display at approximately 01:17:26 EDT.

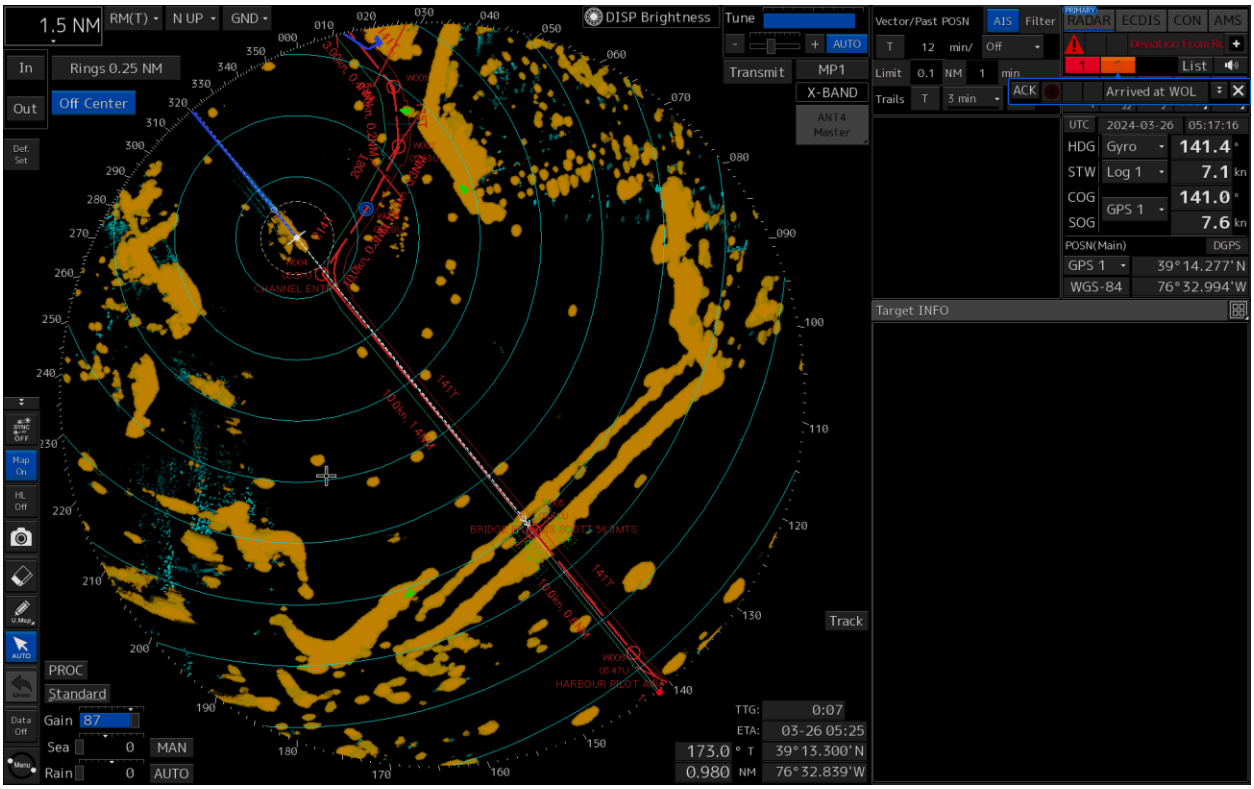

Figure 115. X-Band radar display at approximately 01:17:41 EDT.

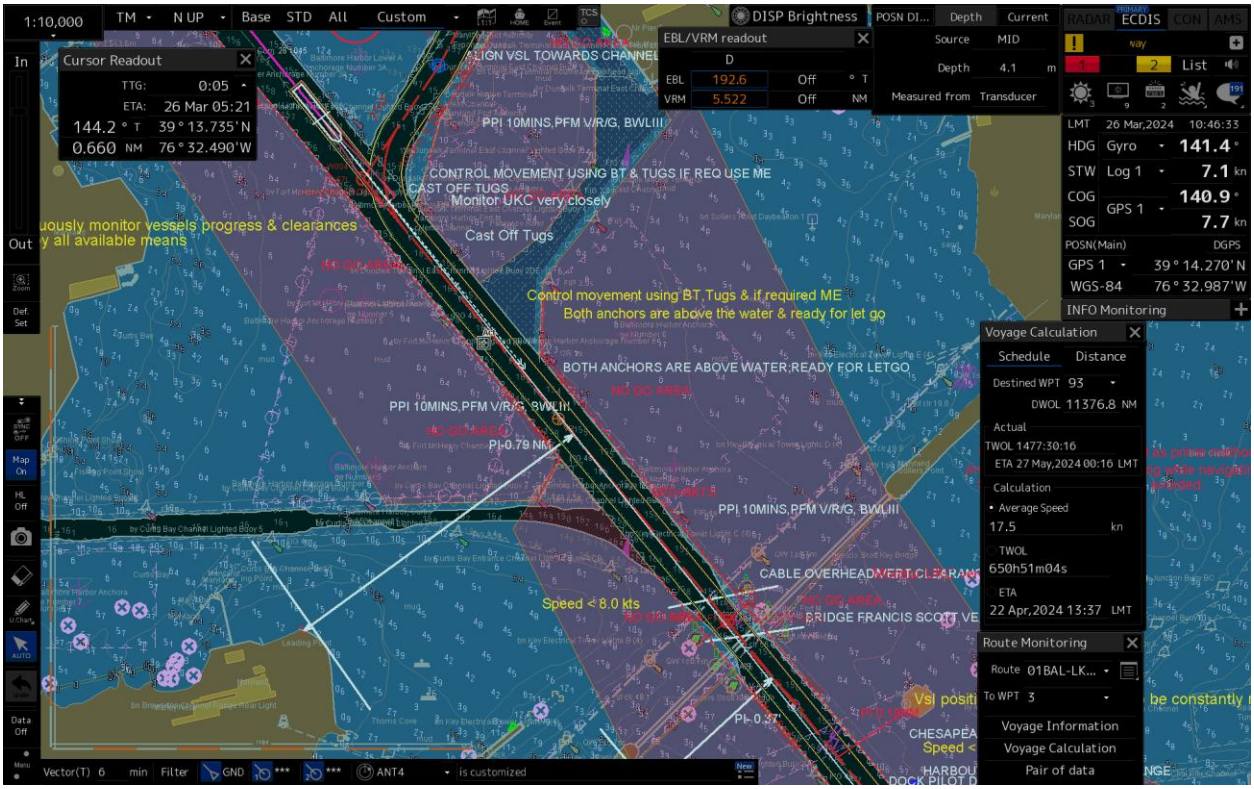

Figure 116. ECDIS display at approximately 01:17:46 EDT.

Figure 117. ECDIS display at approximately 01:17:51 EDT.

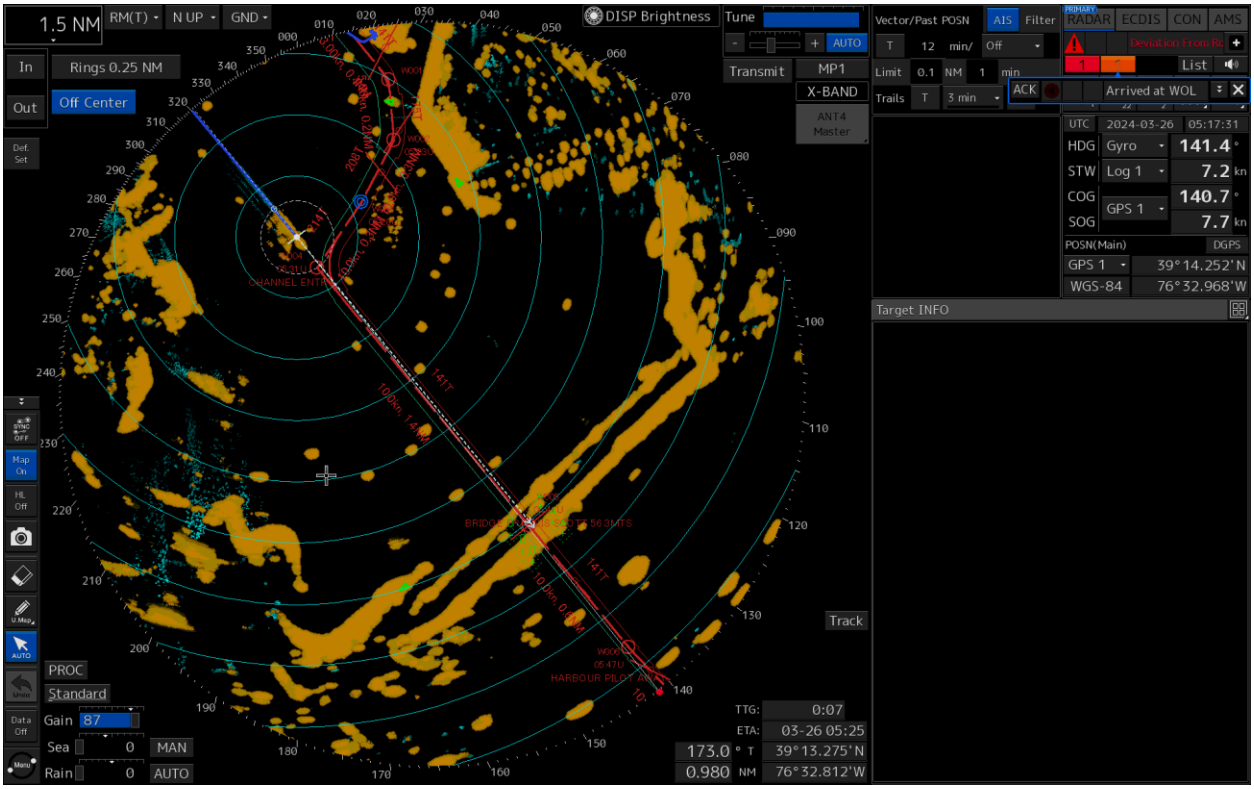

Figure 118. X-Band radar display at approximately 01:17:56 EDT.

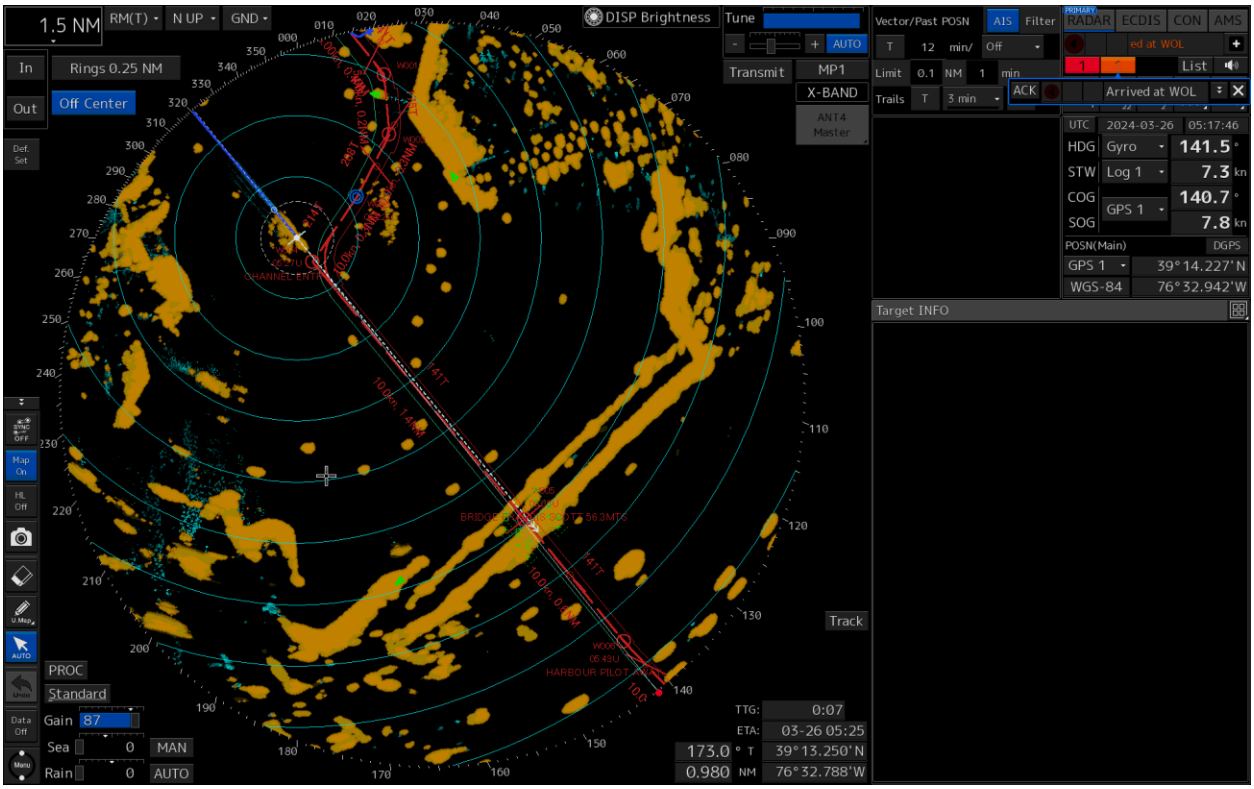

Figure 119. X-Band radar display at approximately 01:18:11 EDT.

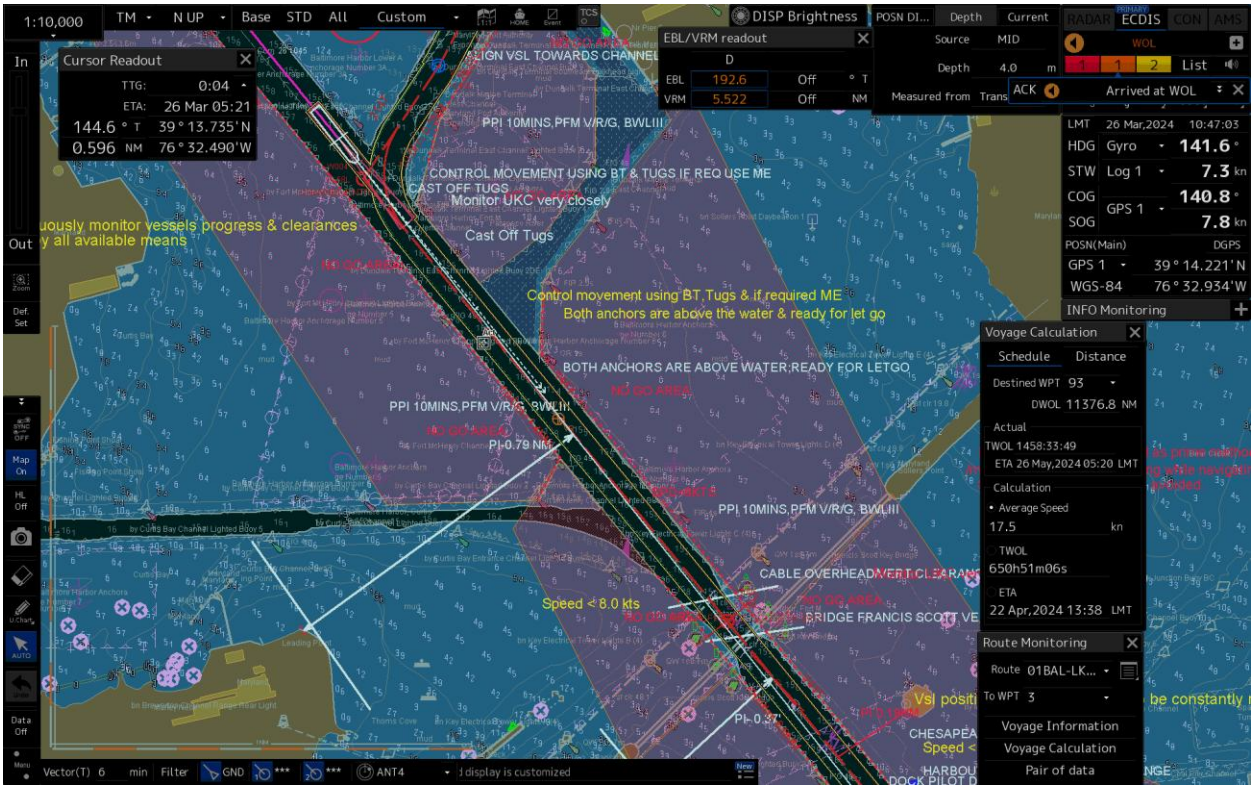

Figure 120. ECDIS display at approximately 01:18:16 EDT.

Figure 121. ECDIS display at approximately 01:18:21 EDT.

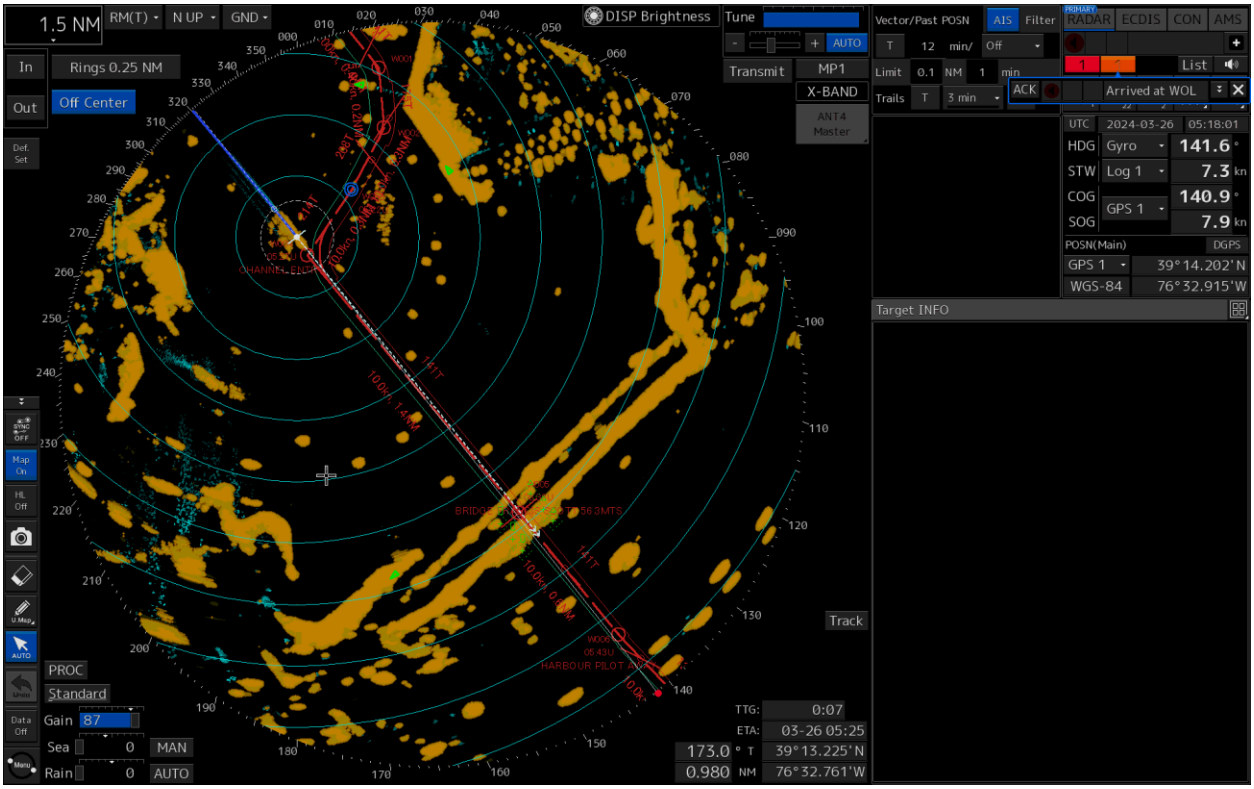

Figure 122. X-Band radar display at approximately 01:18:26 EDT.

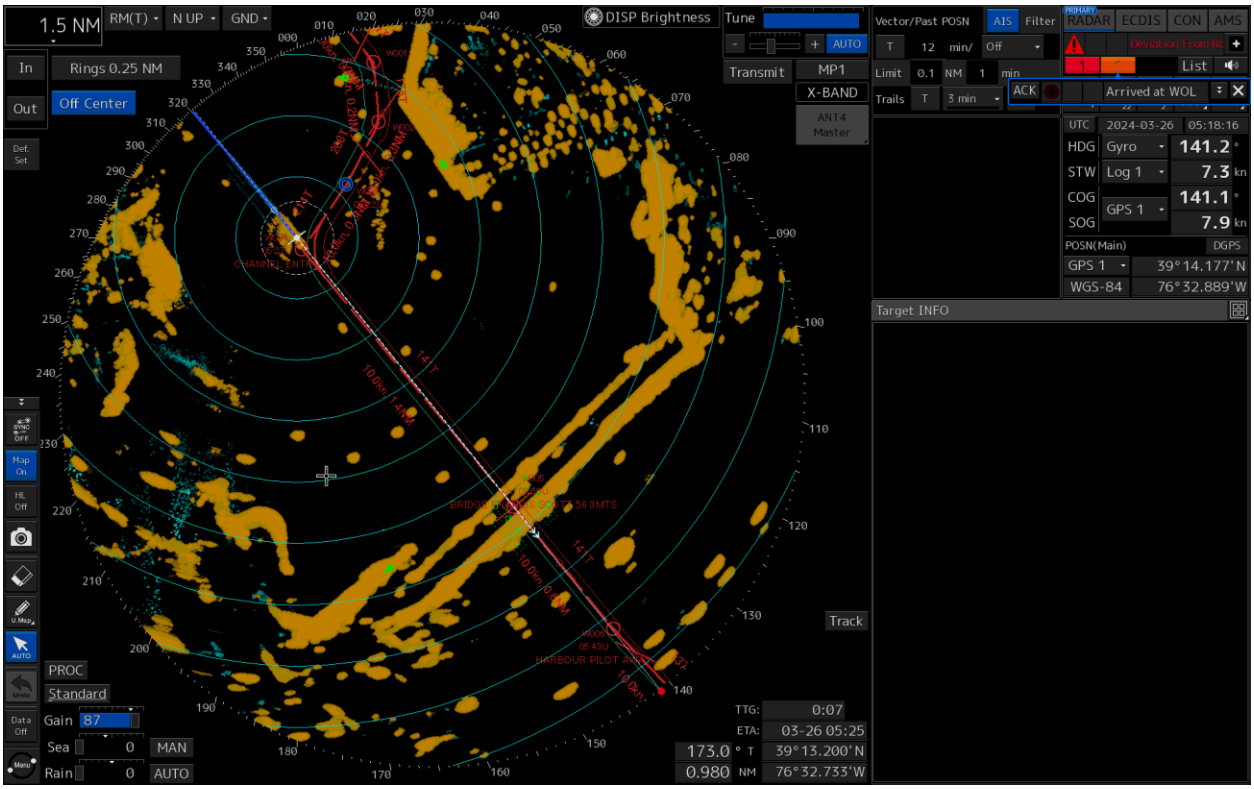

Figure 123. X-Band radar display at approximately 01:18:41 EDT.

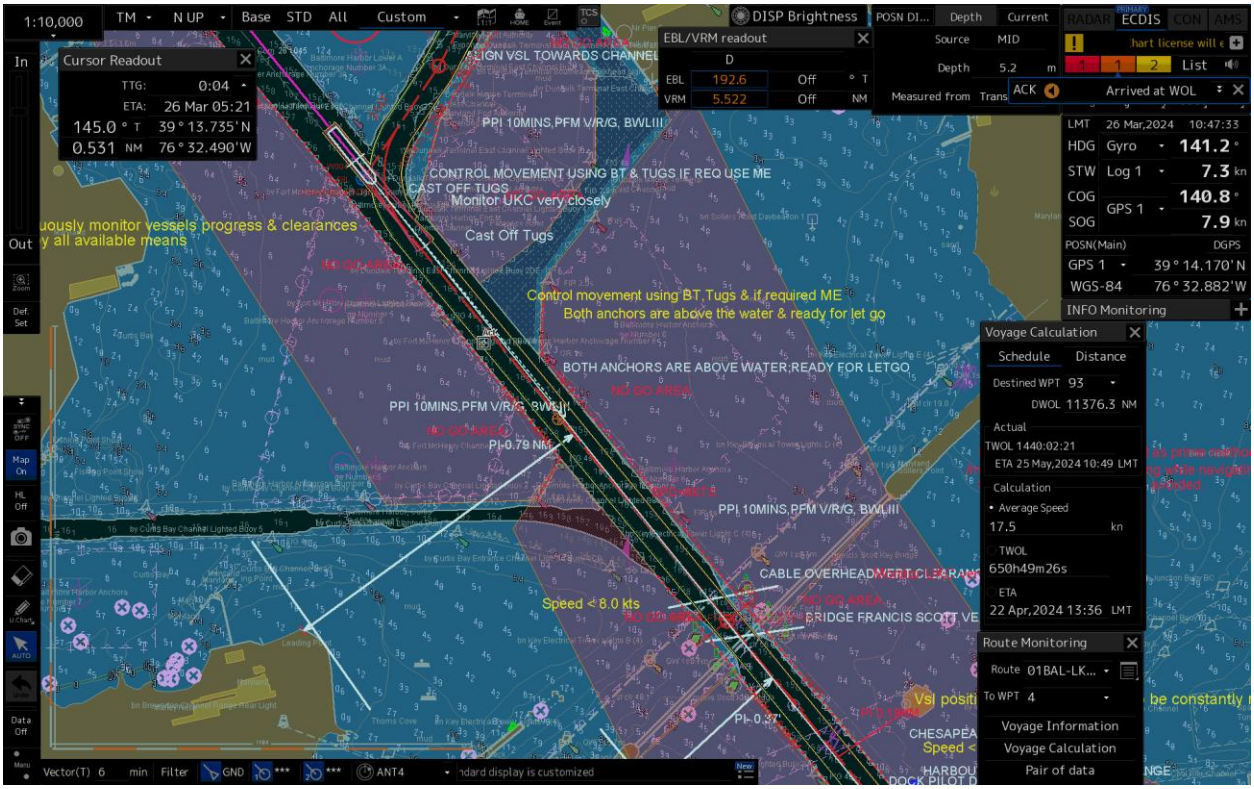

Figure 124. ECDIS display at approximately 01:18:46 EDT.

Figure 125. ECDIS display at approximately 01:18:51 EDT.

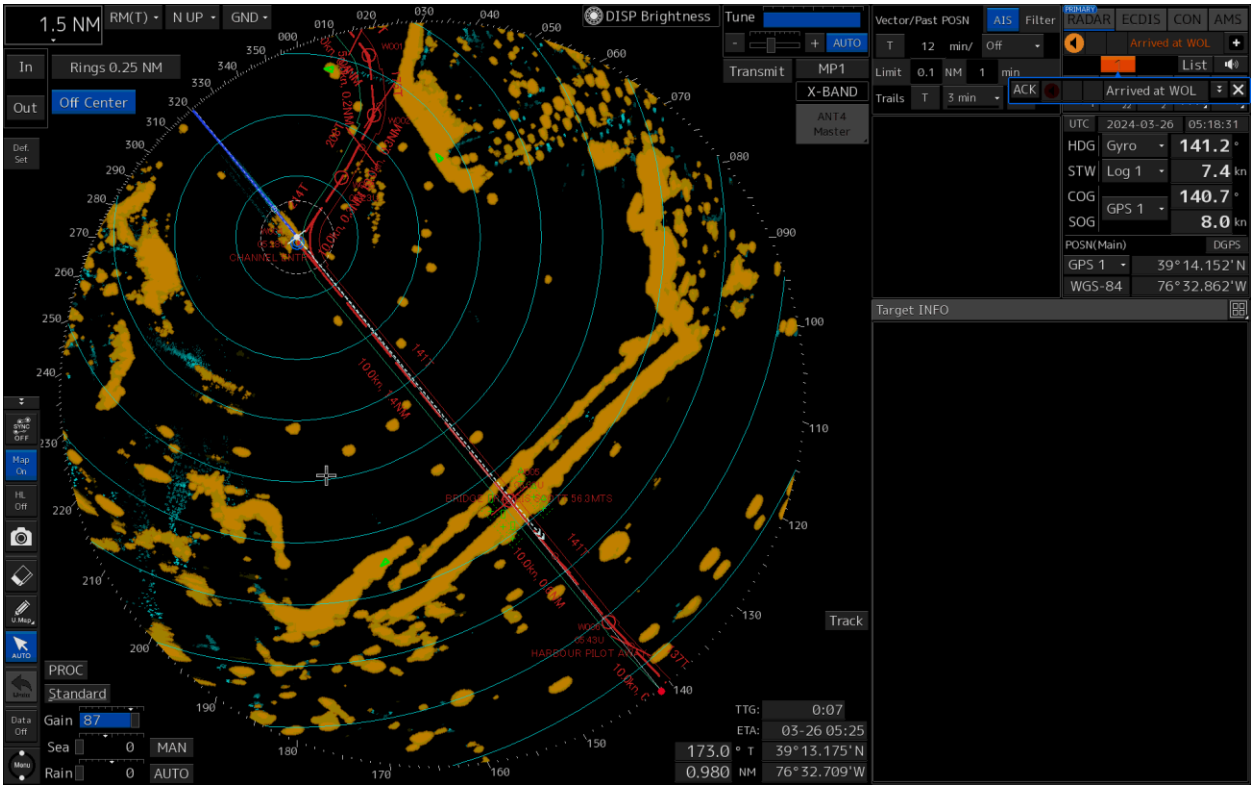

Figure 126. X-Band radar display at approximately 01:18:56 EDT.

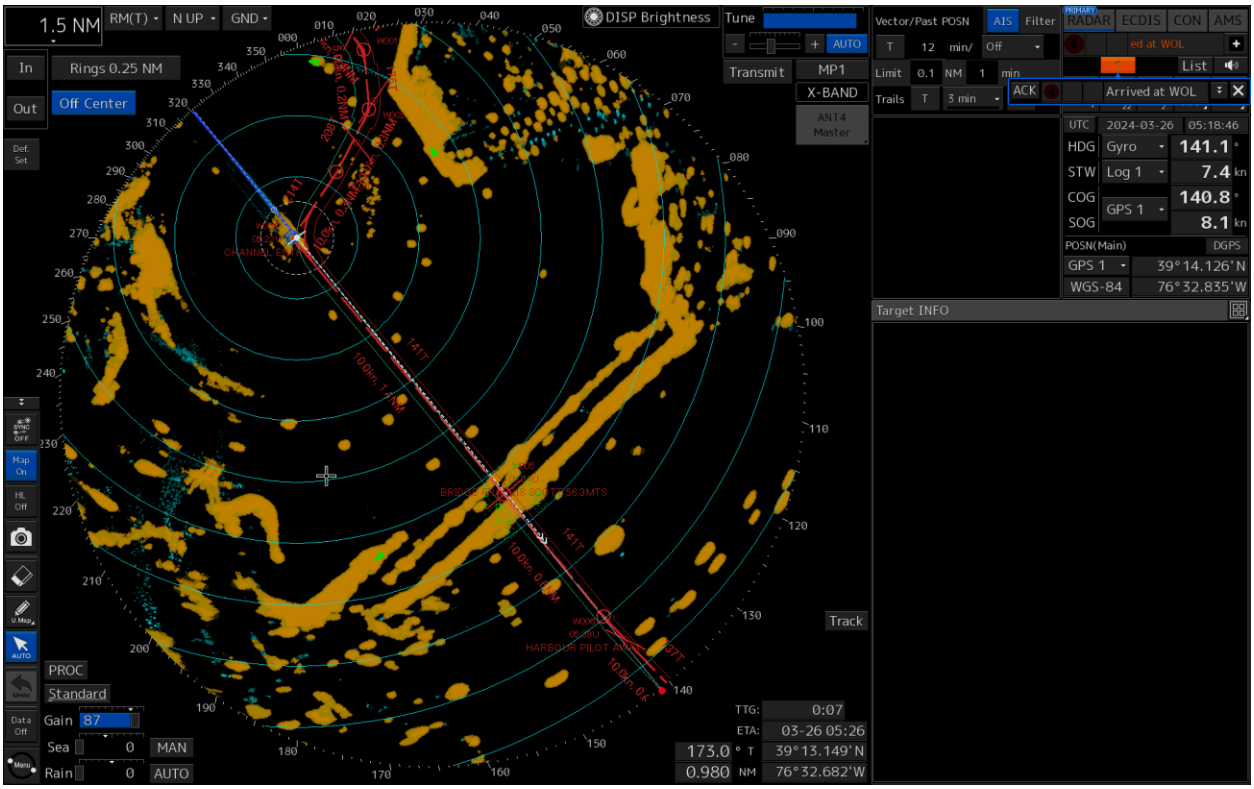

Figure 127. X-Band radar display at approximately 01:19:11 EDT.

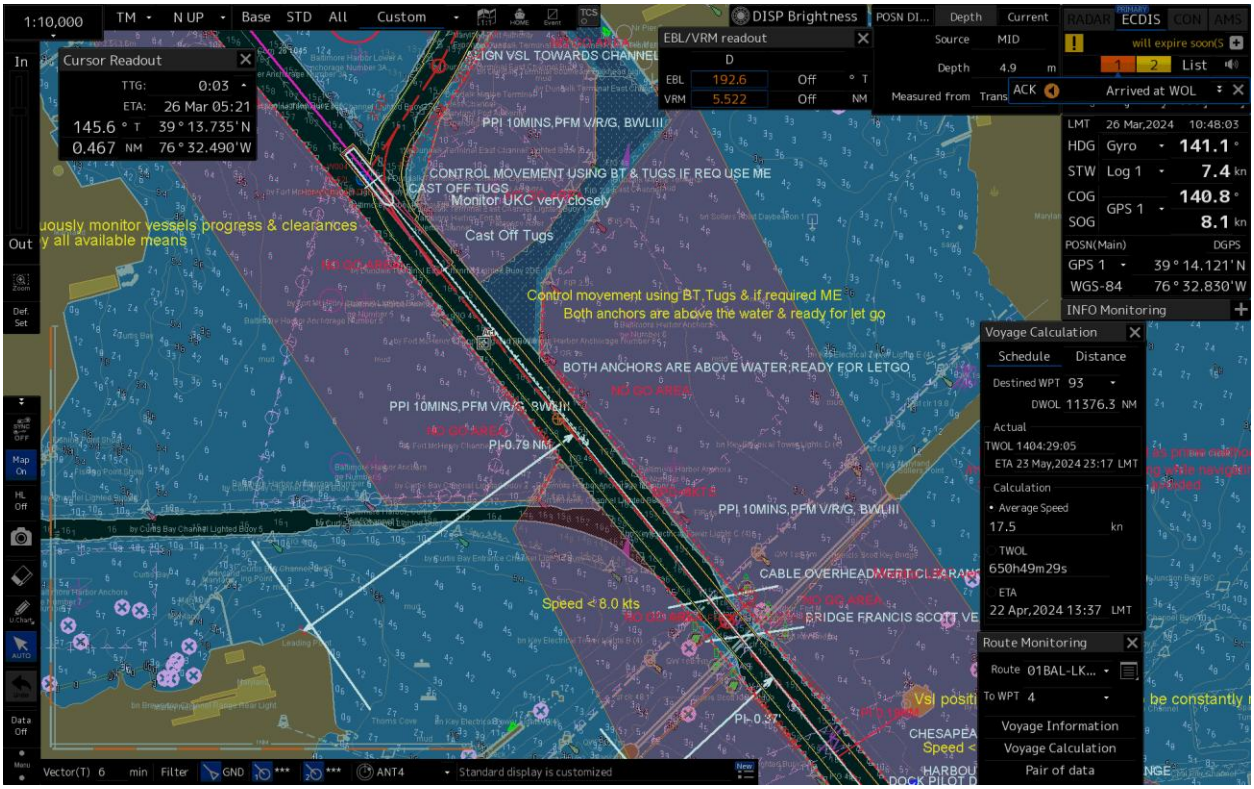

Figure 128. ECDIS display at approximately 01:19:16 EDT.

Figure 129. ECDIS display at approximately 01:19:21 EDT.

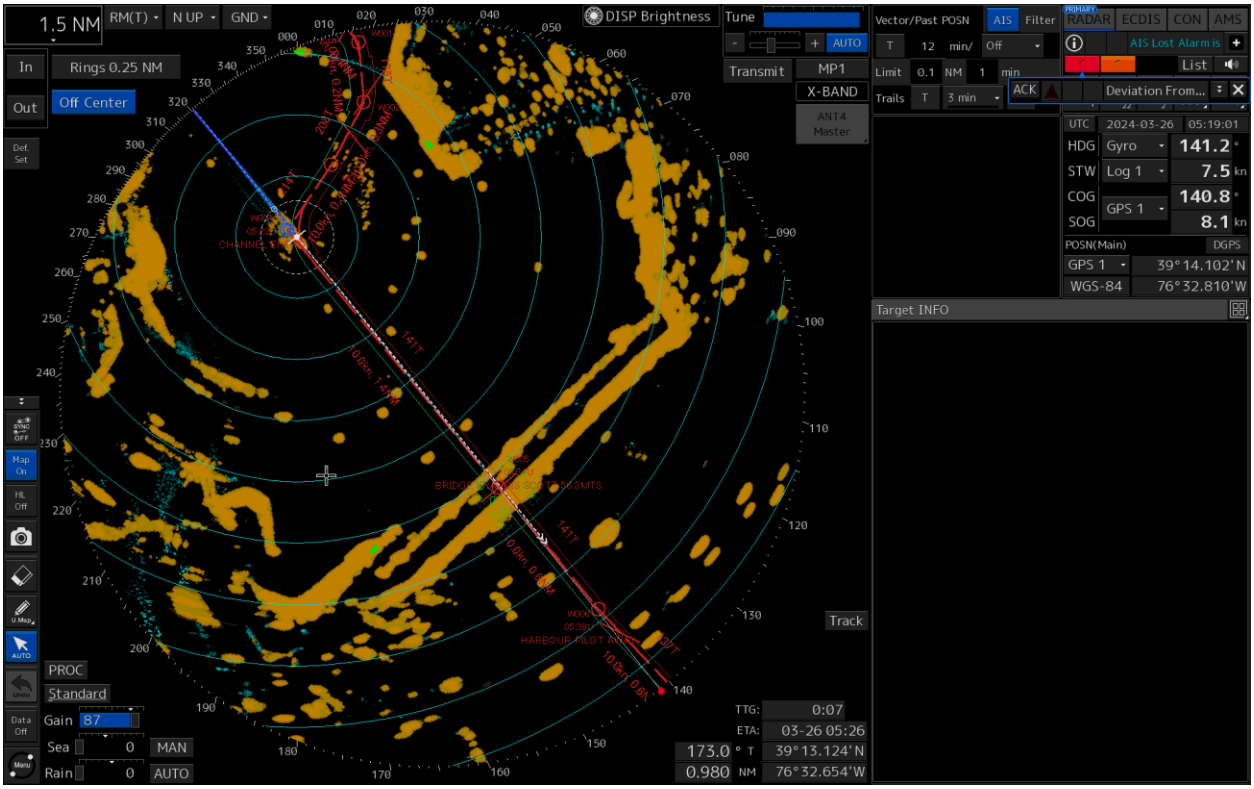

Figure 130. X-Band radar display at approximately 01:19:26 EDT.

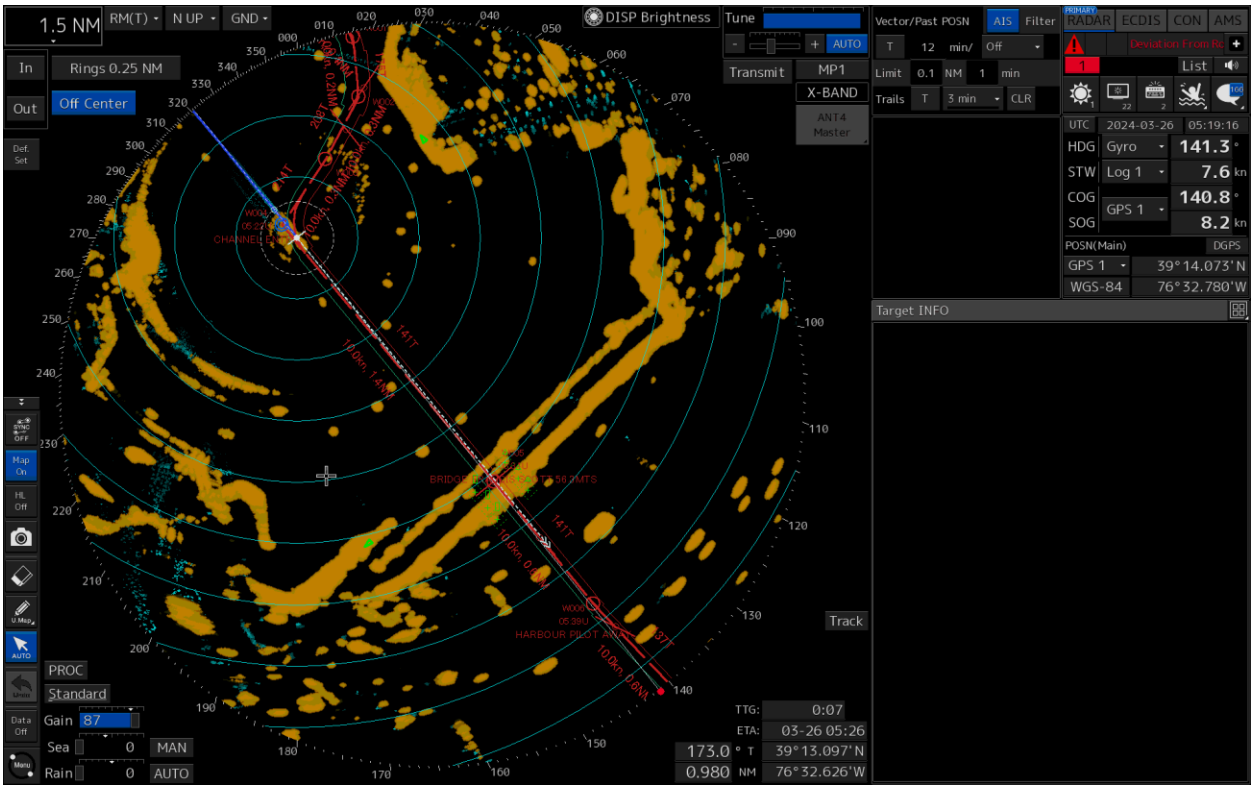

Figure 131. X-Band radar display at approximately 01:19:41 EDT.

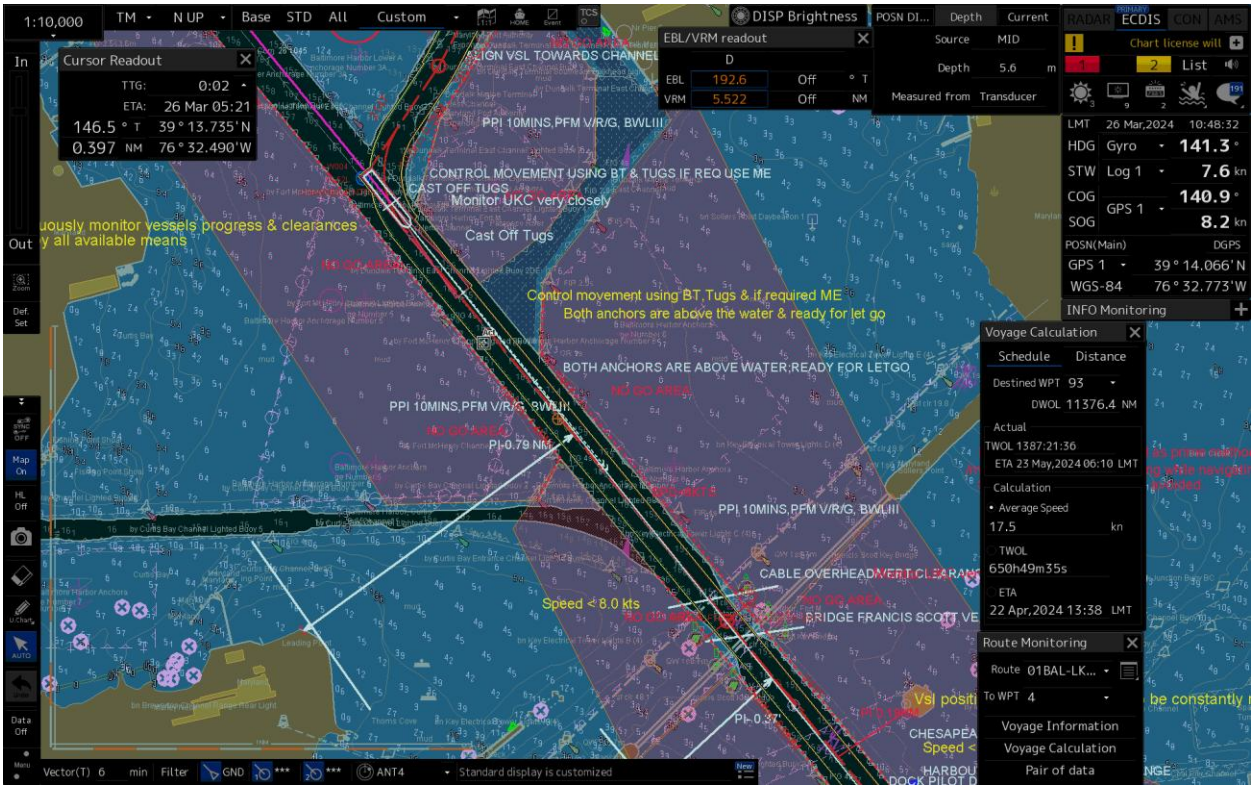

Figure 132. ECDIS display at approximately 01:19:45 EDT.

Figure 133. ECDIS display at approximately 01:19:51 EDT.

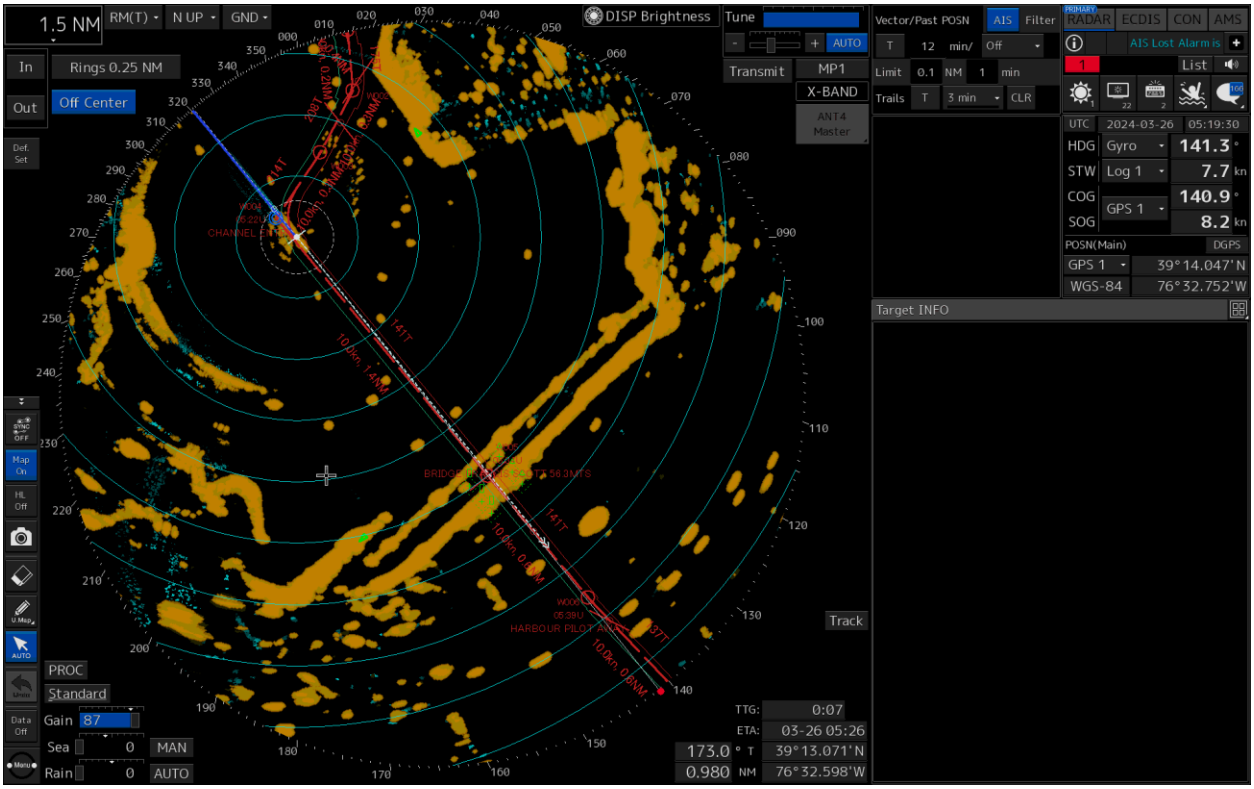

Figure 134. X-Band radar display at approximately 01:19:55 EDT.

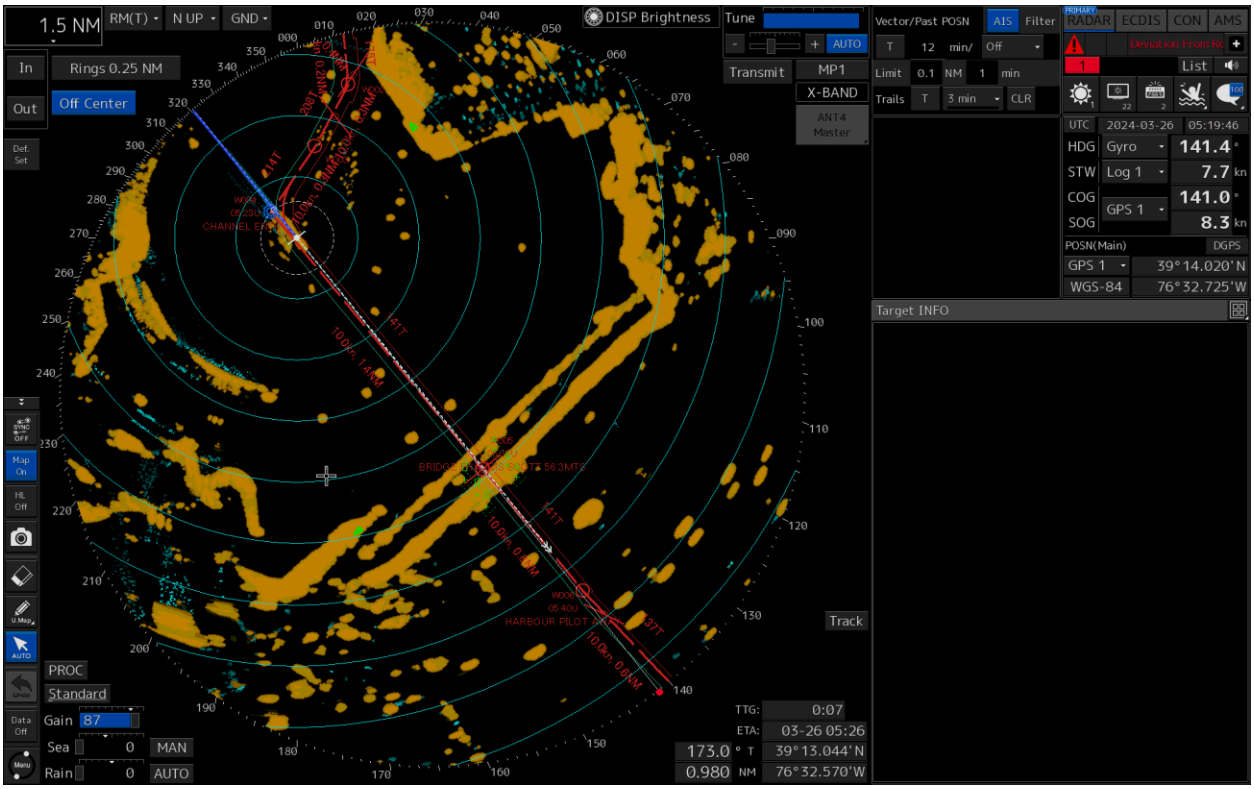

Figure 135. X-Band radar display at approximately 01:20:11 EDT.

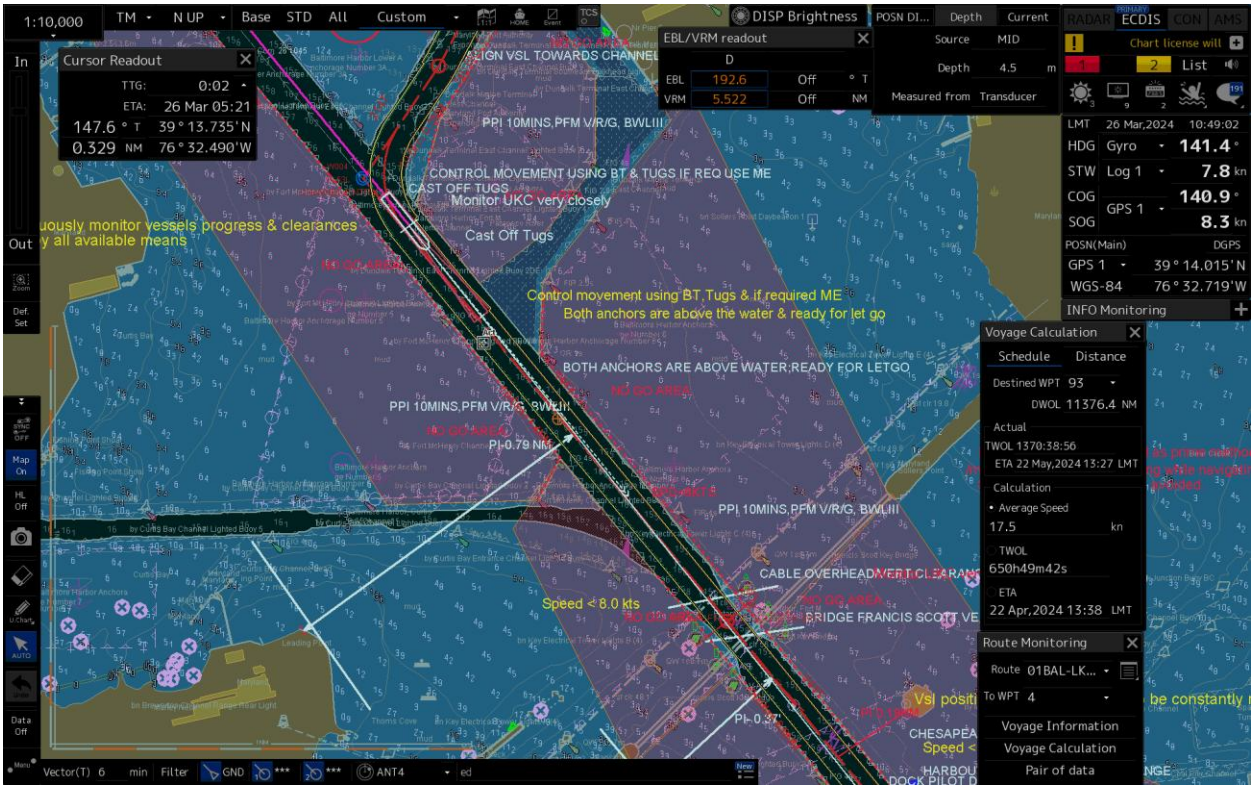

Figure 136. ECDIS display at approximately 01:20:15 EDT.

Figure 137. ECDIS display at approximately 01:20:21 EDT.

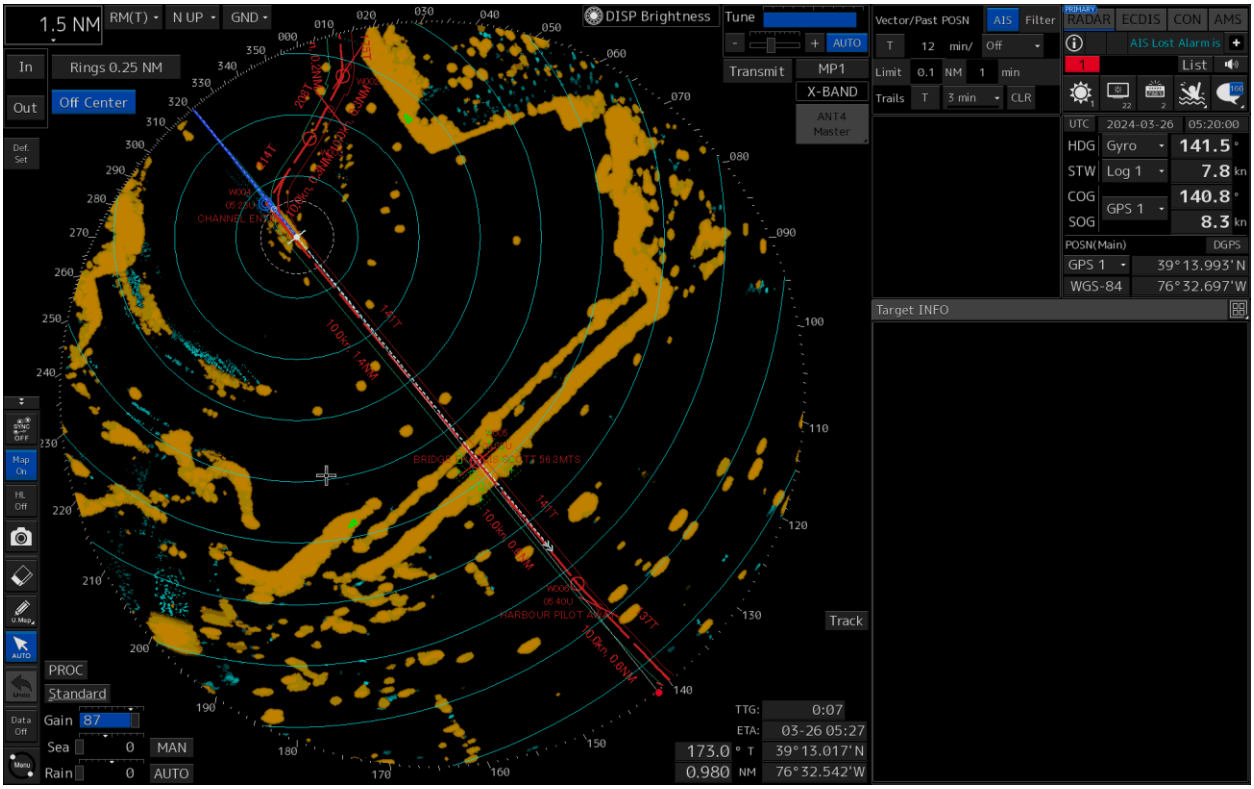

Figure 138. X-Band radar display at approximately 01:20:25 EDT.

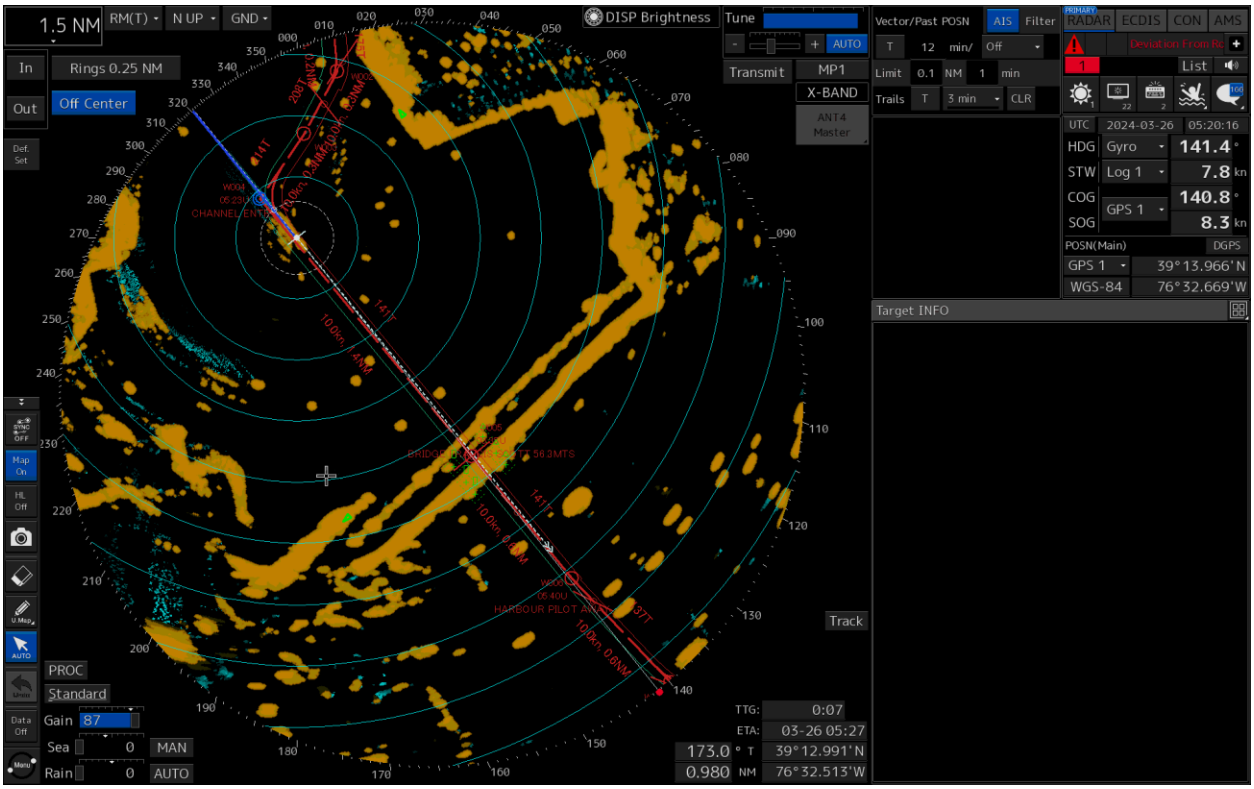

Figure 139. X-Band radar display at approximately 01:20:41 EDT.

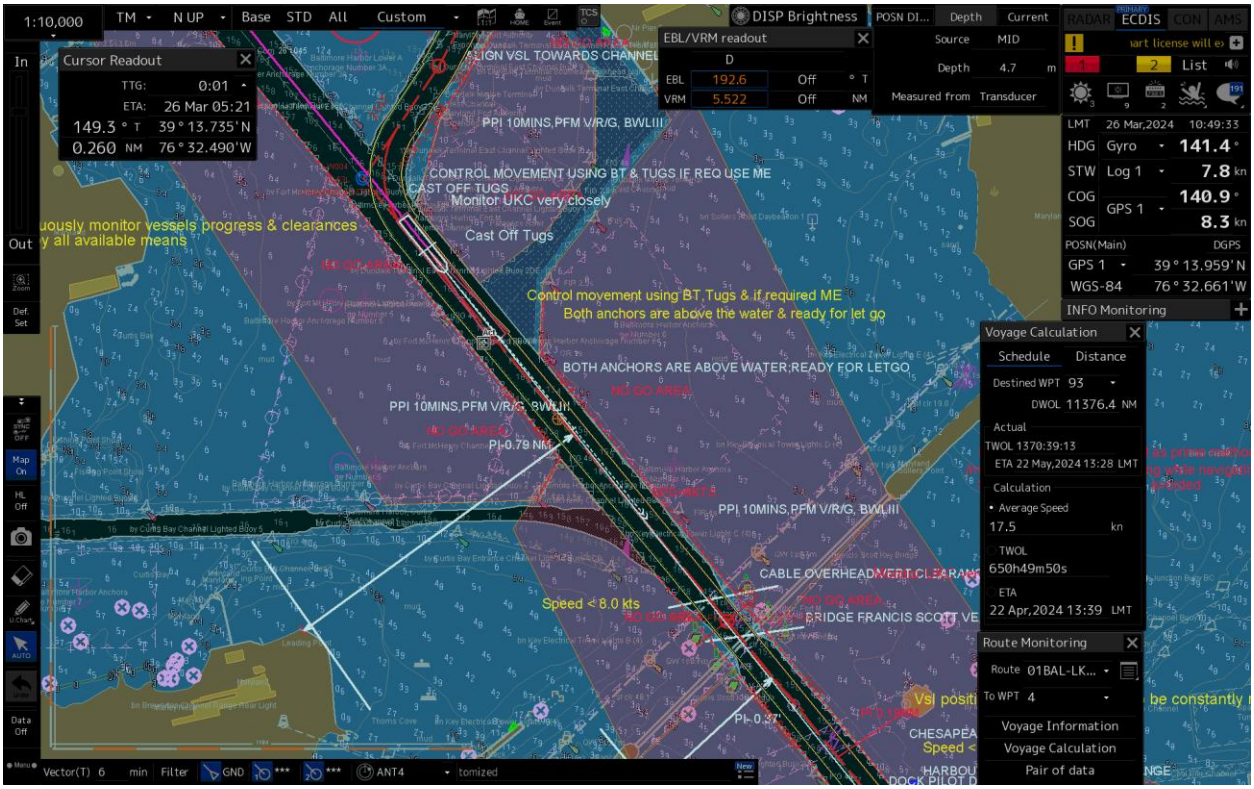

Figure 140. ECDIS display at approximately 01:20:46 EDT.

Figure 141. ECDIS display at approximately 01:20:51 EDT.

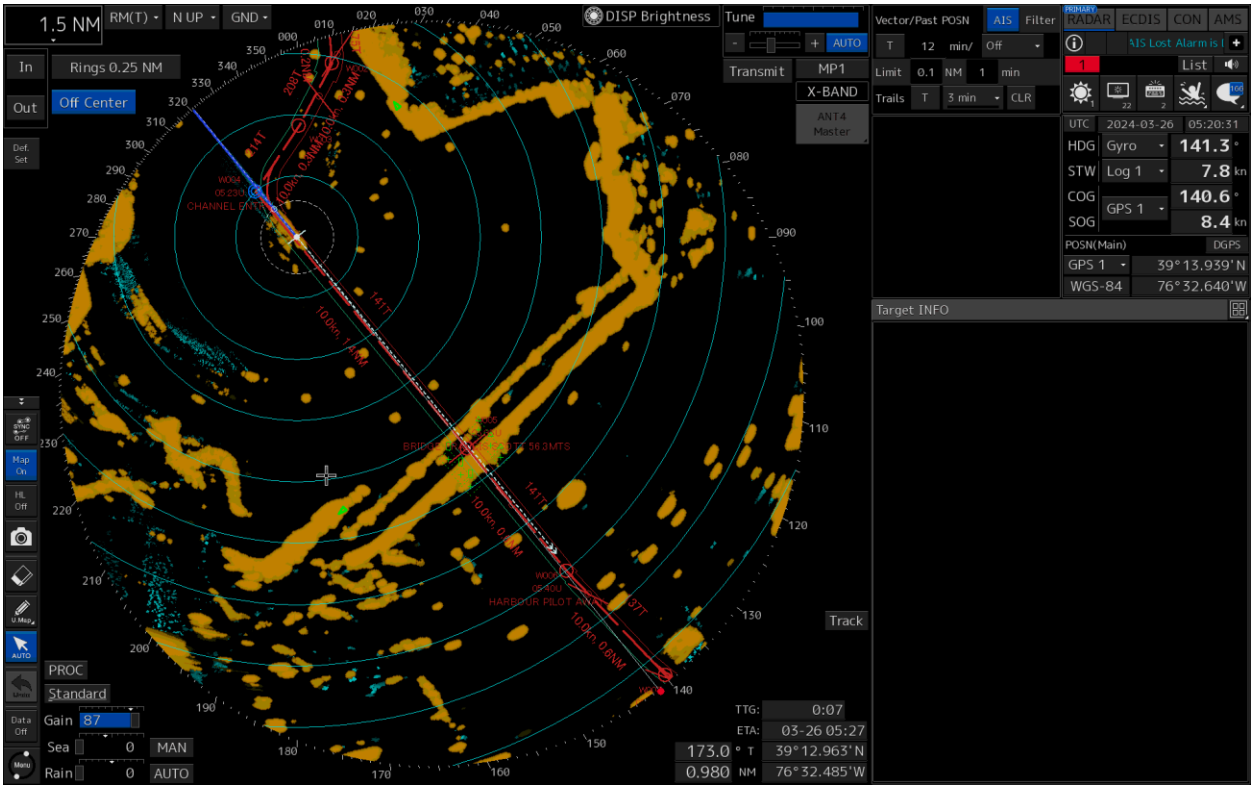

Figure 142. X-Band radar display at approximately 01:20:56 EDT.

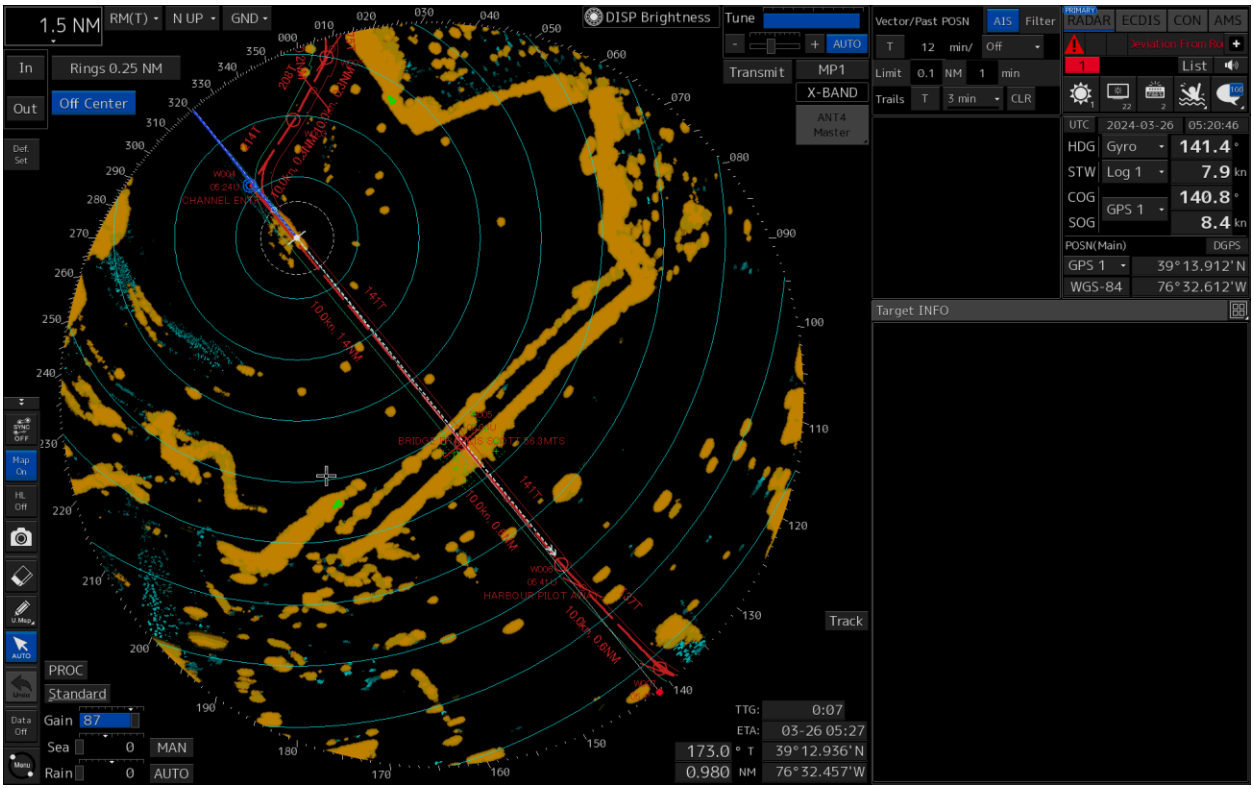

Figure 143. X-Band radar display at approximately 01:21:11 EDT.

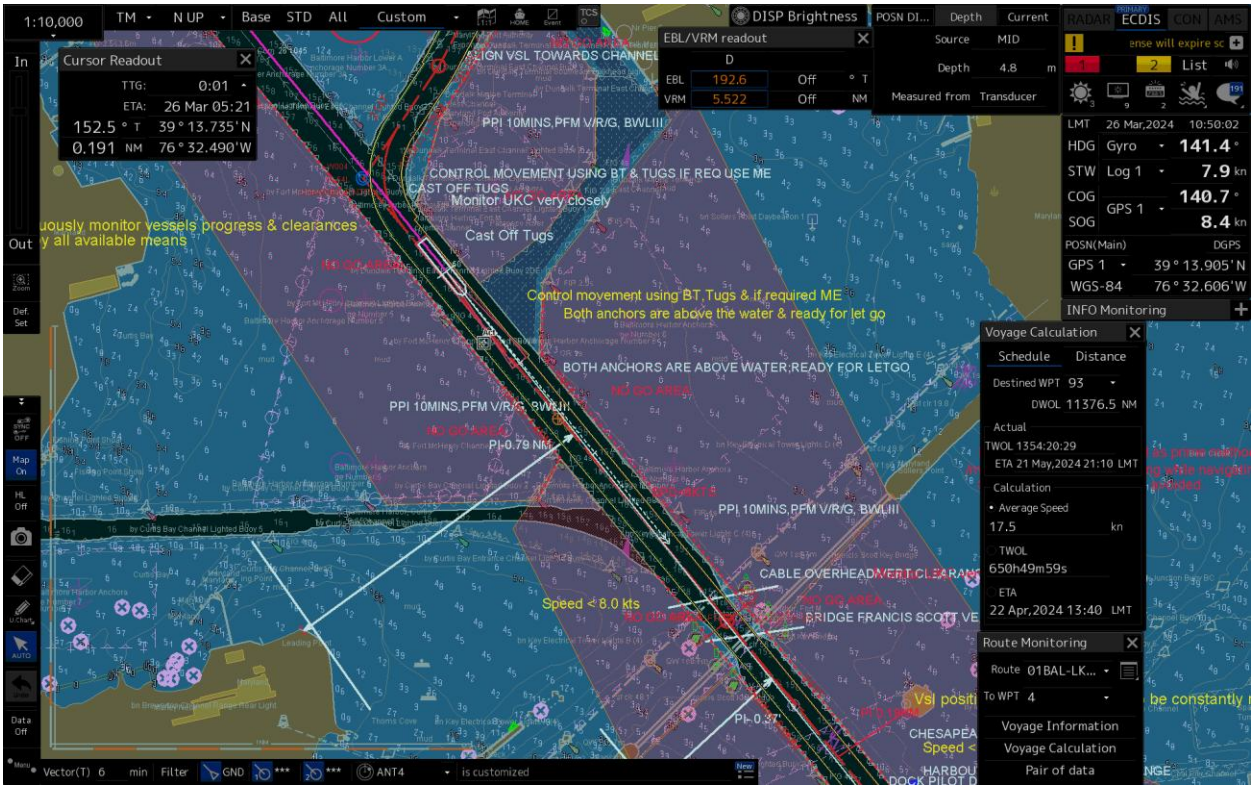

Figure 144. ECDIS display at approximately 01:21:15 EDT.

Figure 145. ECDIS display at approximately 01:21:21 EDT.

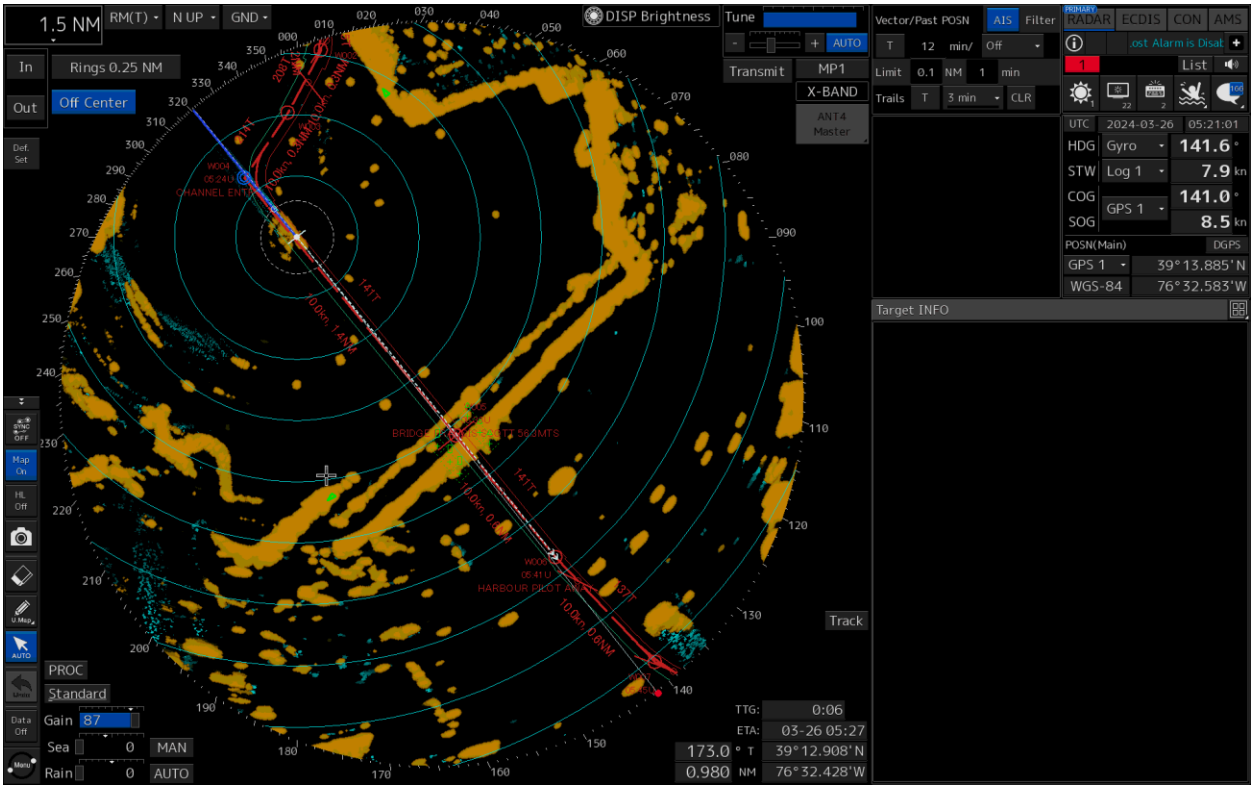

Figure 146. X-Band radar display at approximately 01:21:26 EDT.

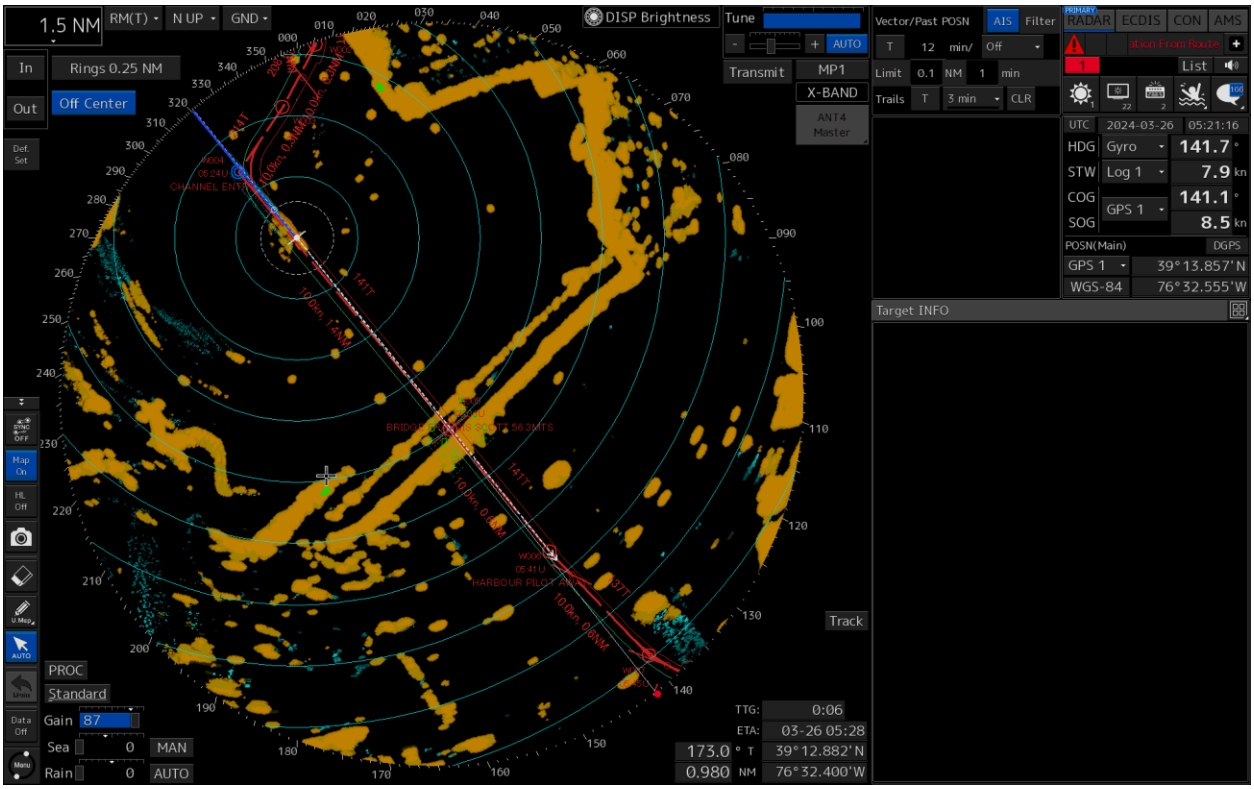

Figure 147. X-Band radar display at approximately 01:21:41 EDT.

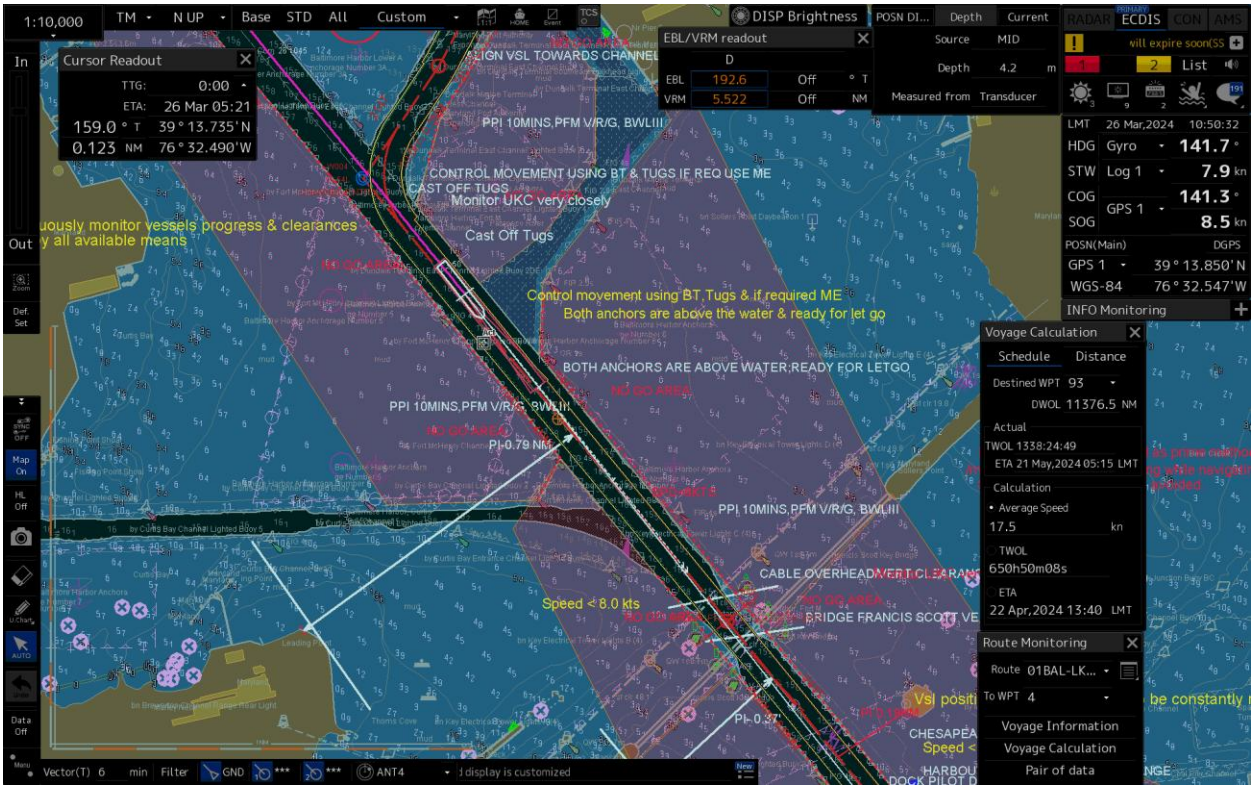

Figure 148. ECDIS display at approximately 01:21:45 EDT.

Figure 149. ECDIS display at approximately 01:21:51 EDT.

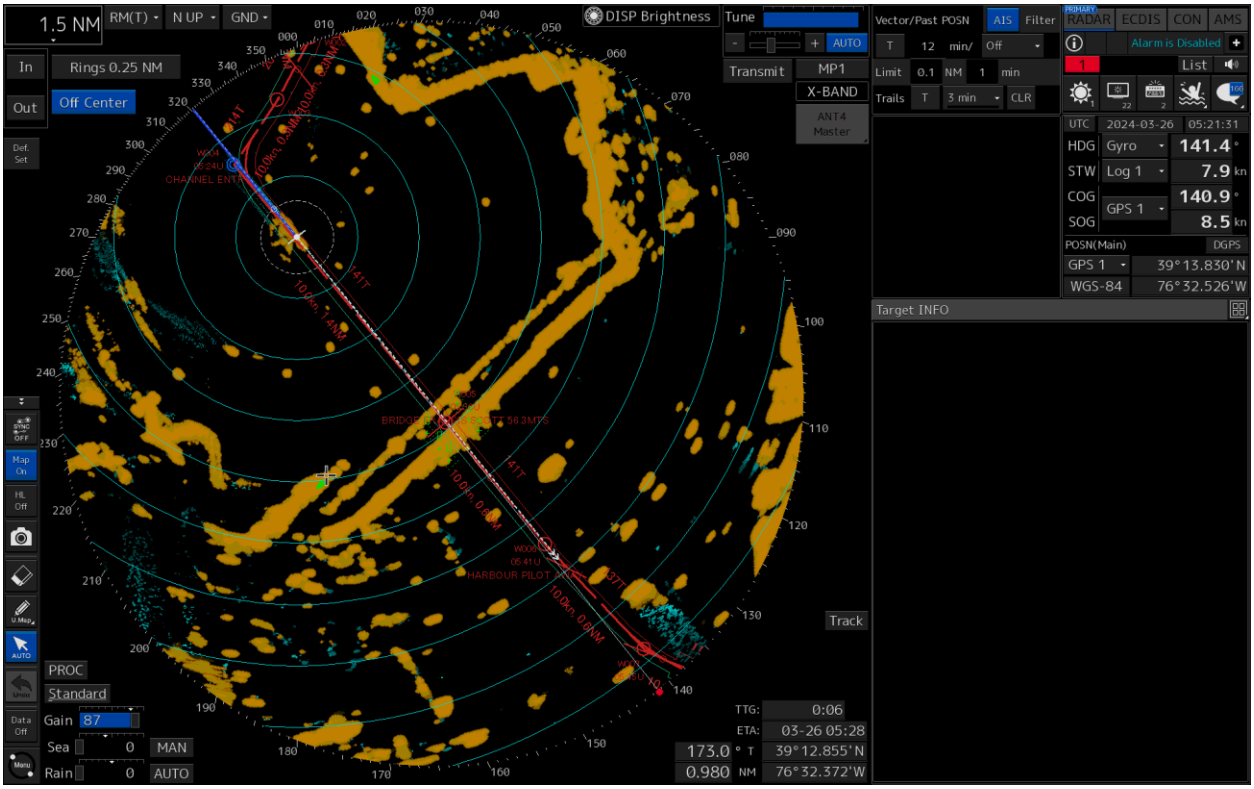

Figure 150. X-Band radar display at approximately 01:21:56 EDT.

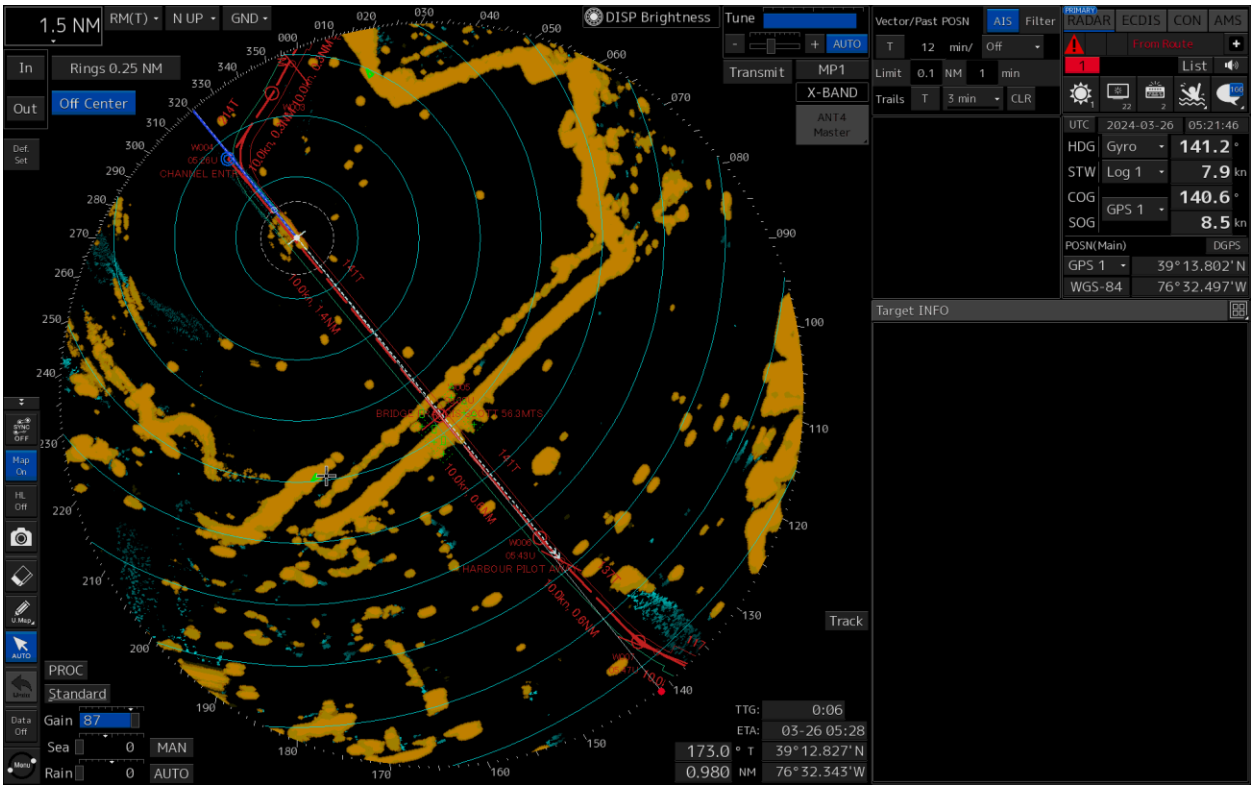

Figure 151. X-Band radar display at approximately 01:22:11 EDT.

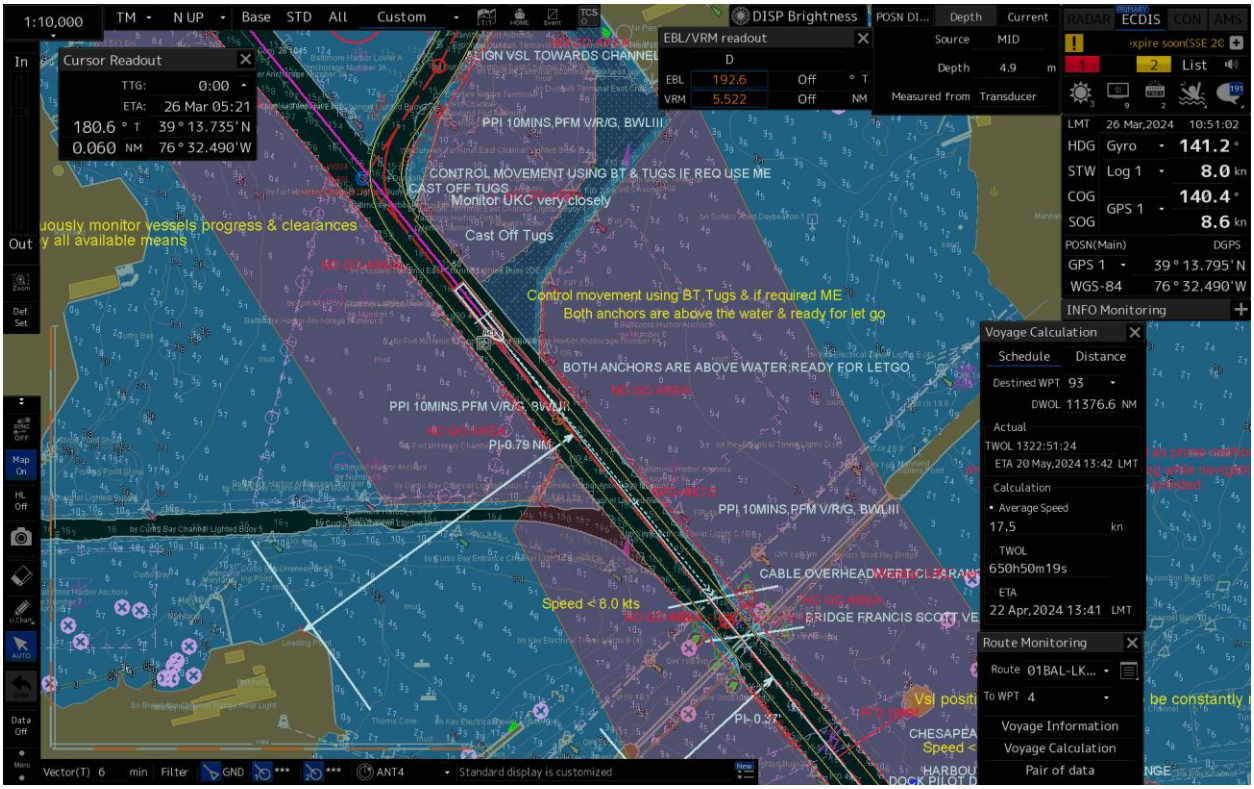

Figure 152. ECDIS display at approximately 01:22:15 EDT.

Figure 153. ECDIS display at approximately 01:22:21 EDT.

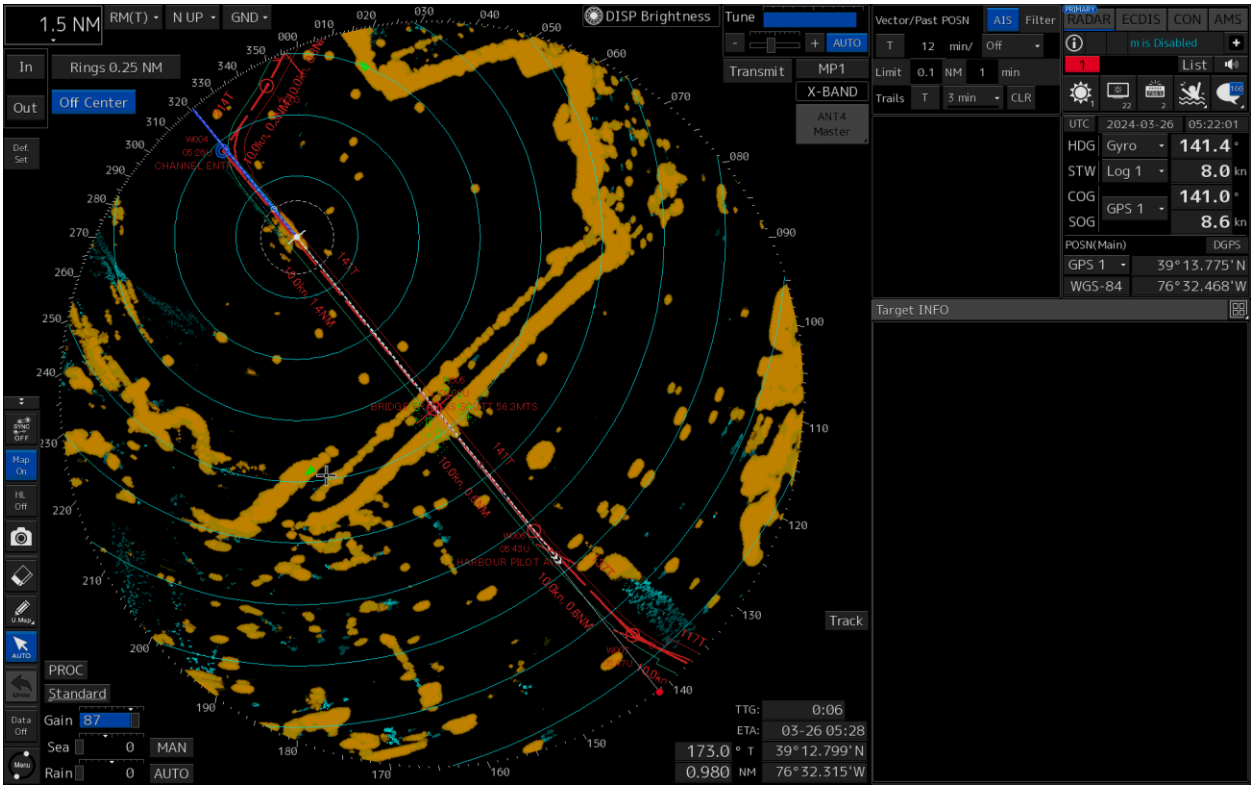

Figure 154. X-Band radar display at approximately 01:22:26 EDT.

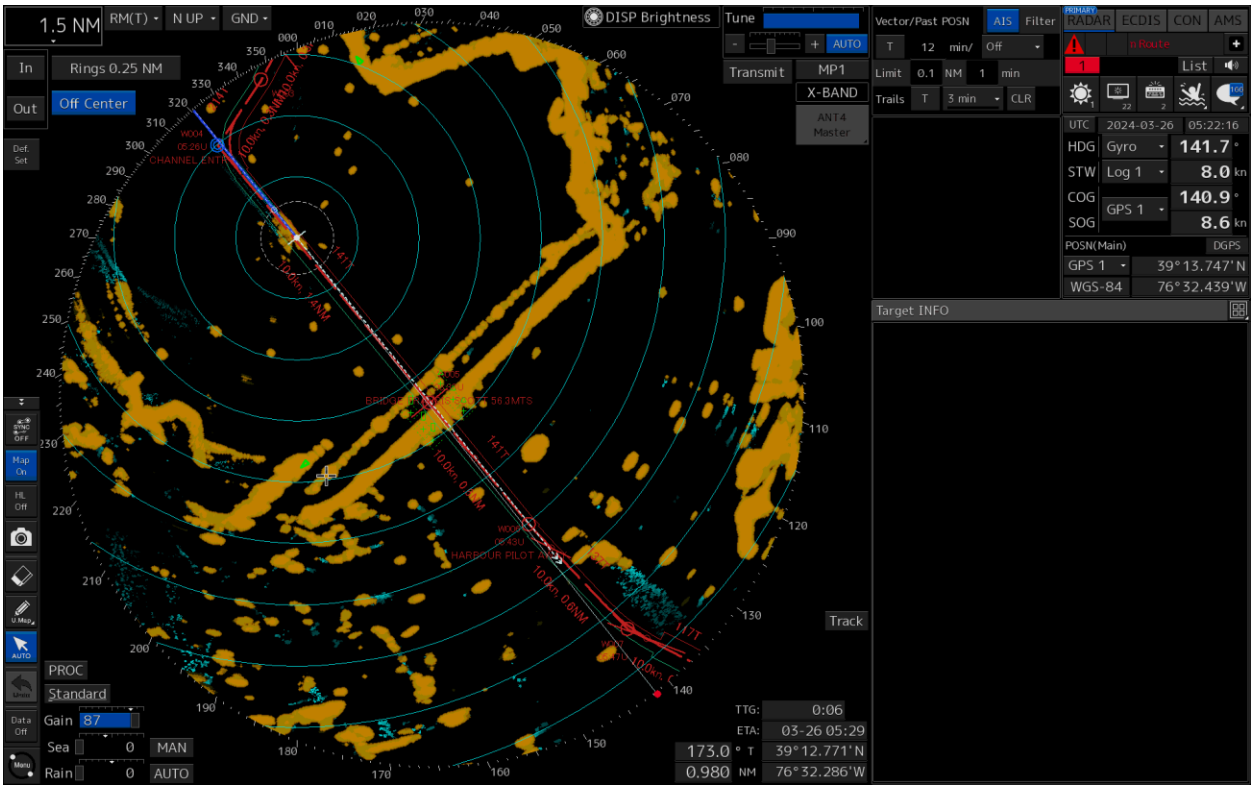

Figure 155. X-Band radar display at approximately 01:22:41 EDT.

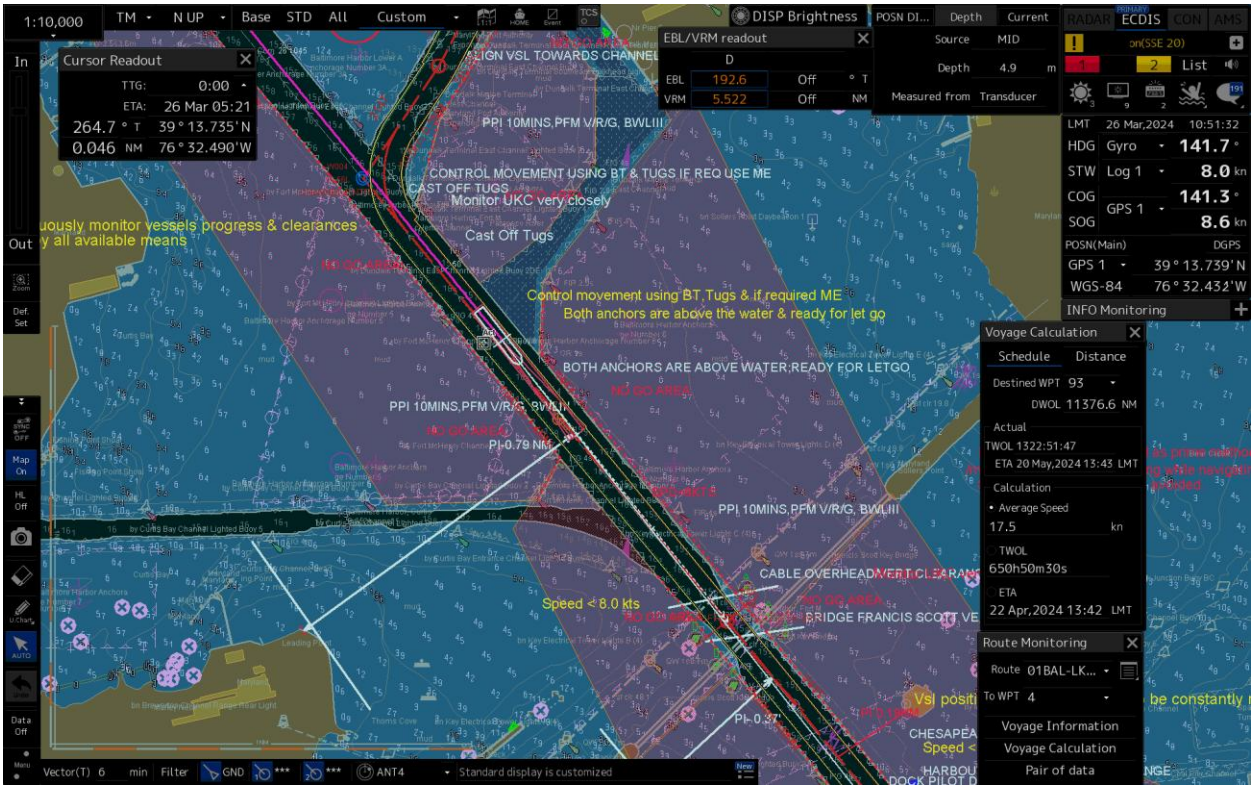

Figure 156. ECDIS display at approximately 01:22:45 EDT.

Figure 157. ECDIS display at approximately 01:22:51 EDT.

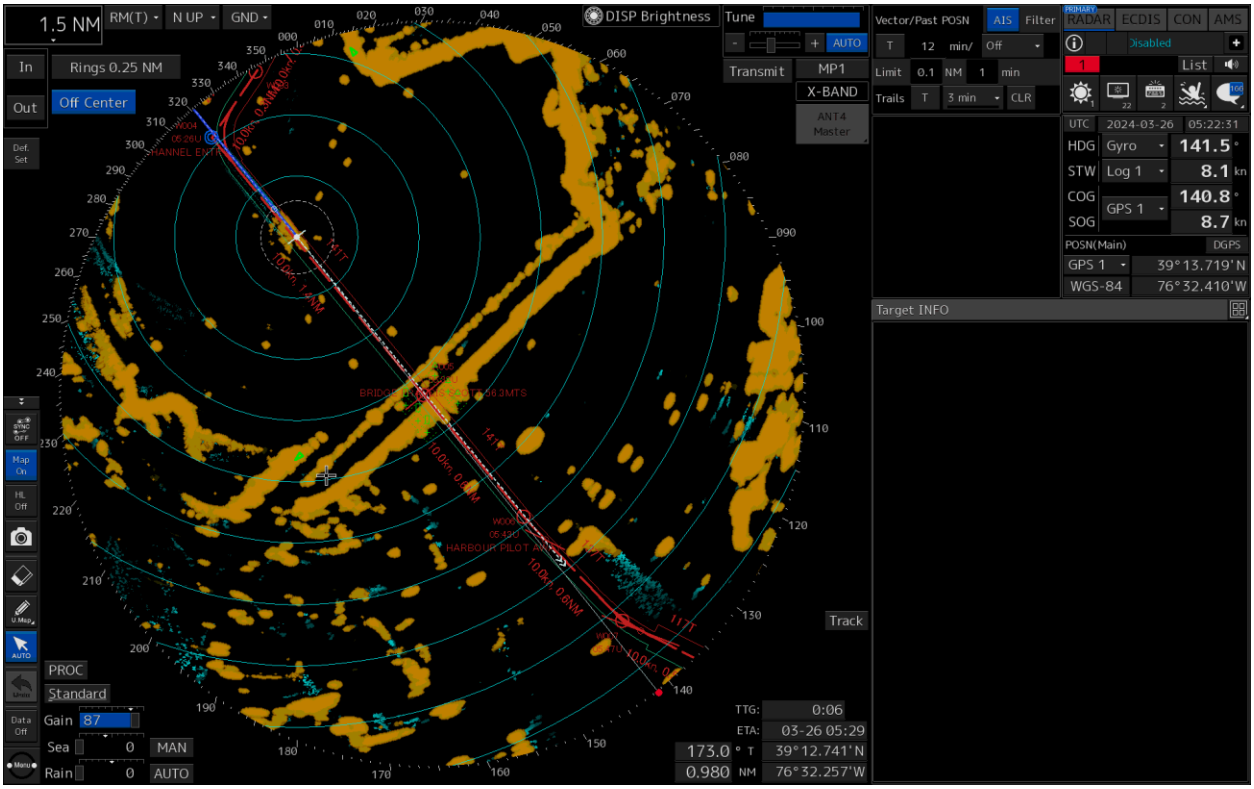

Figure 158. X-Band radar display at approximately 01:22:56 EDT.

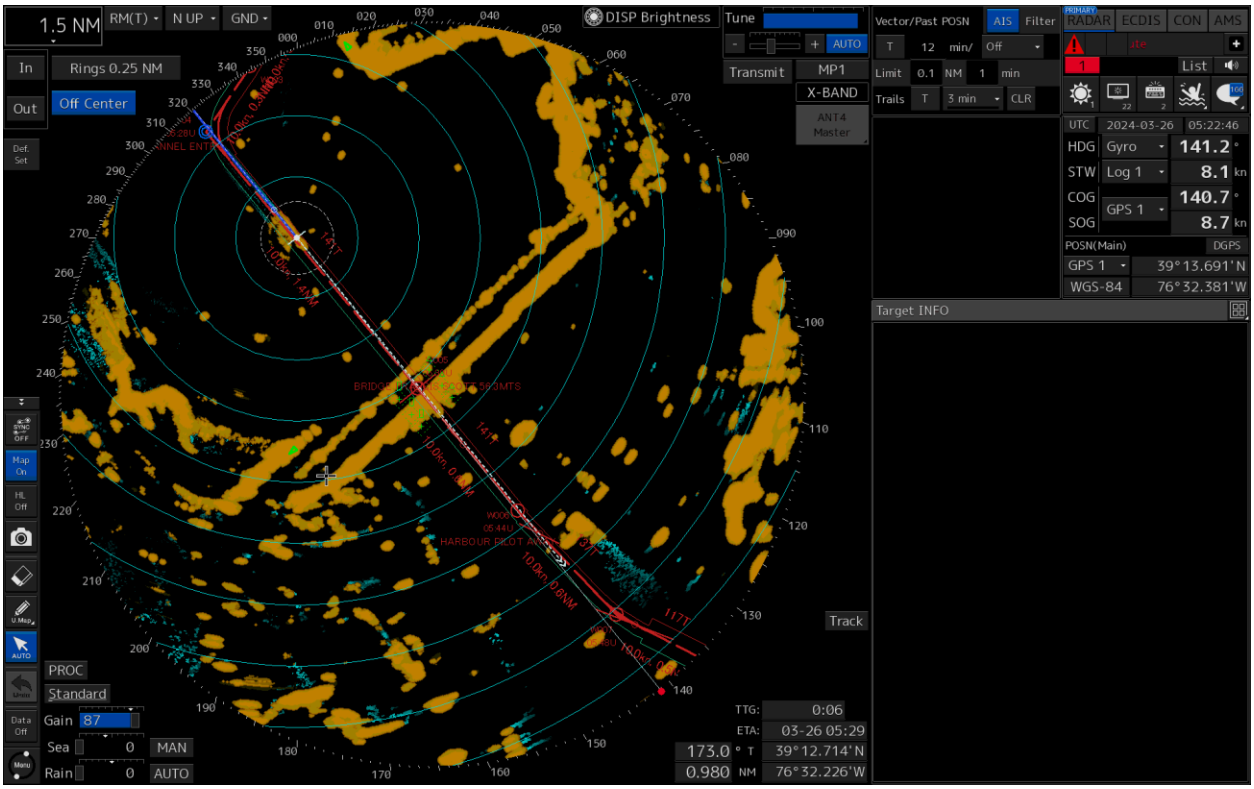

Figure 159. X-Band radar display at approximately 01:23:11 EDT.

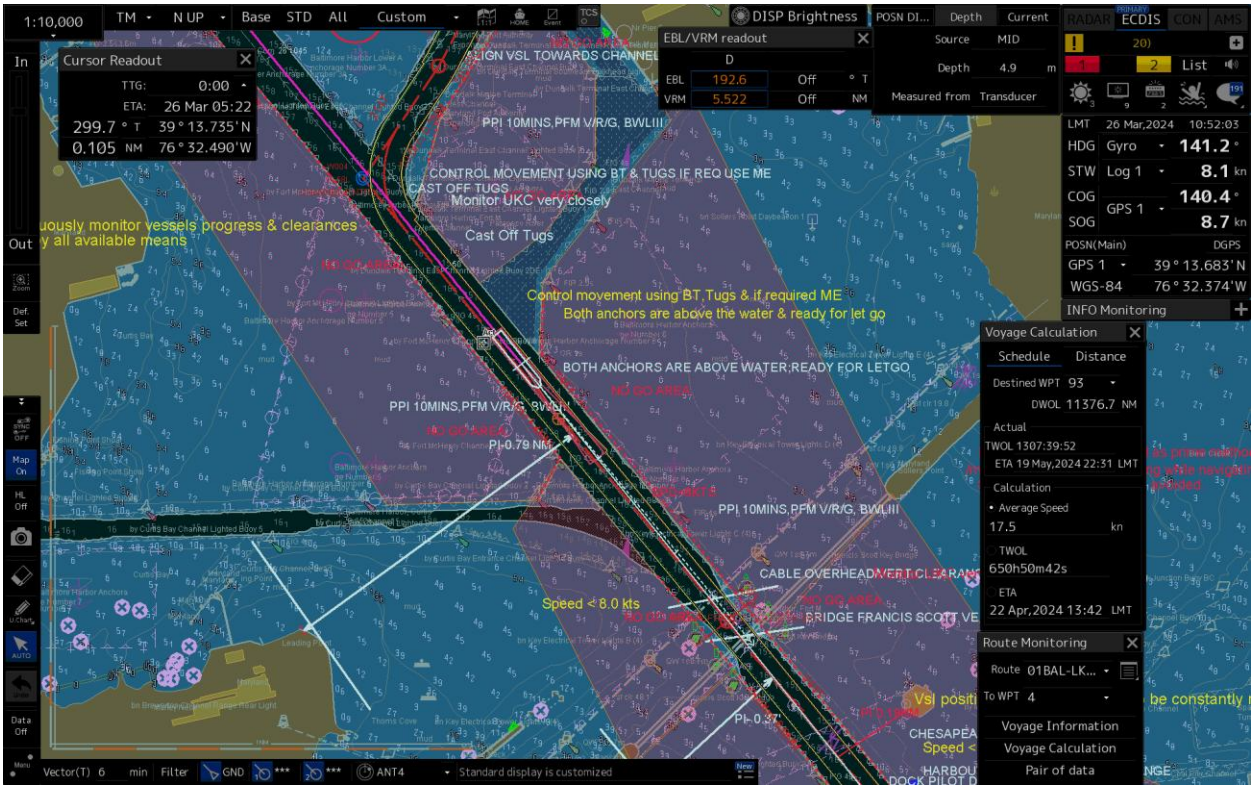

Figure 160. ECDIS display at approximately 01:23:16 EDT.

Figure 161. ECDIS display at approximately 01:23:21 EDT.

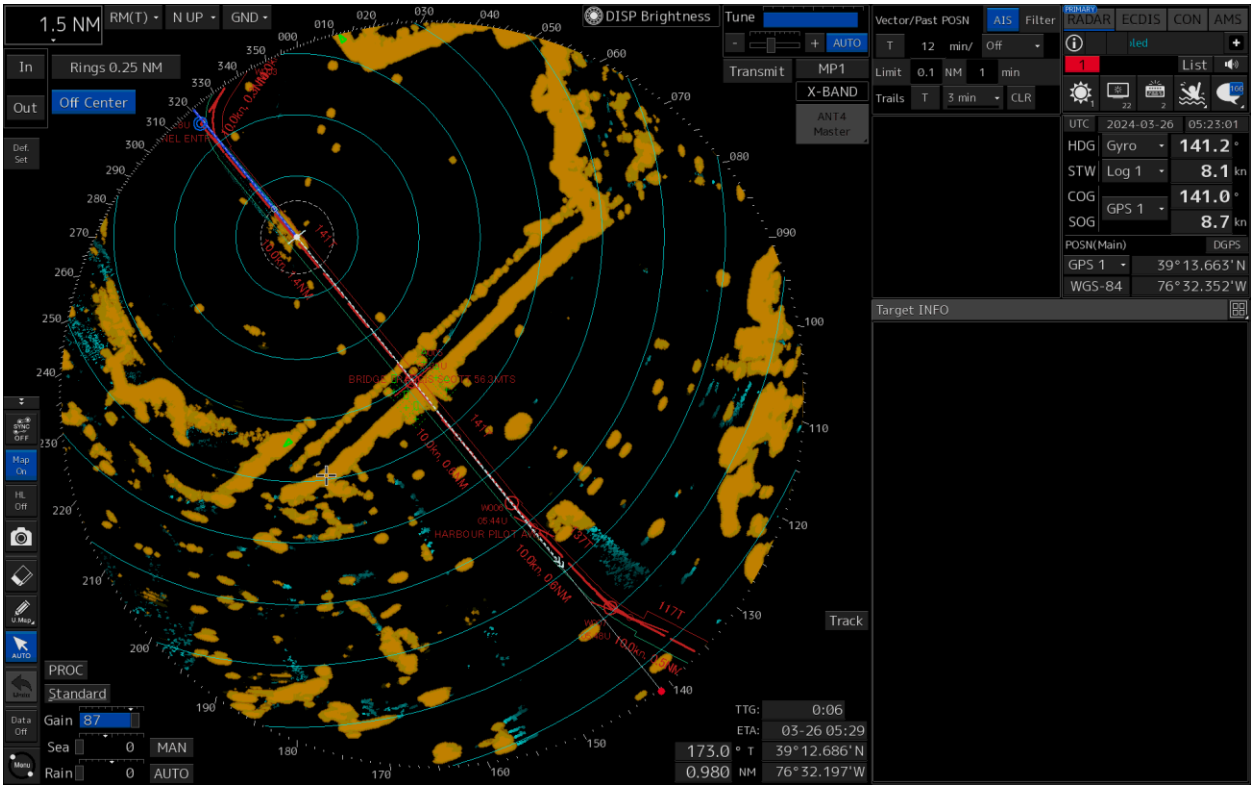

Figure 162. X-Band radar display at approximately 01:23:26 EDT.

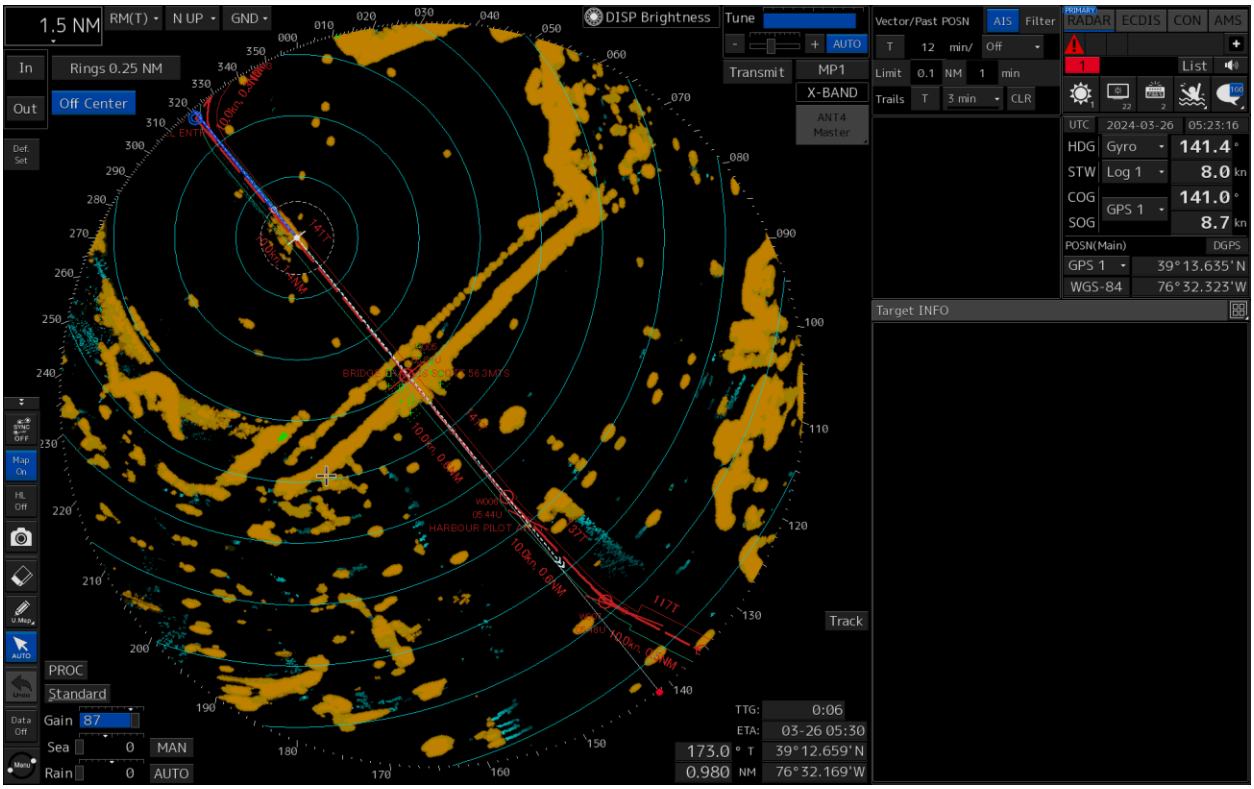

Figure 163. X-Band radar display at approximately 01:23:41 EDT.

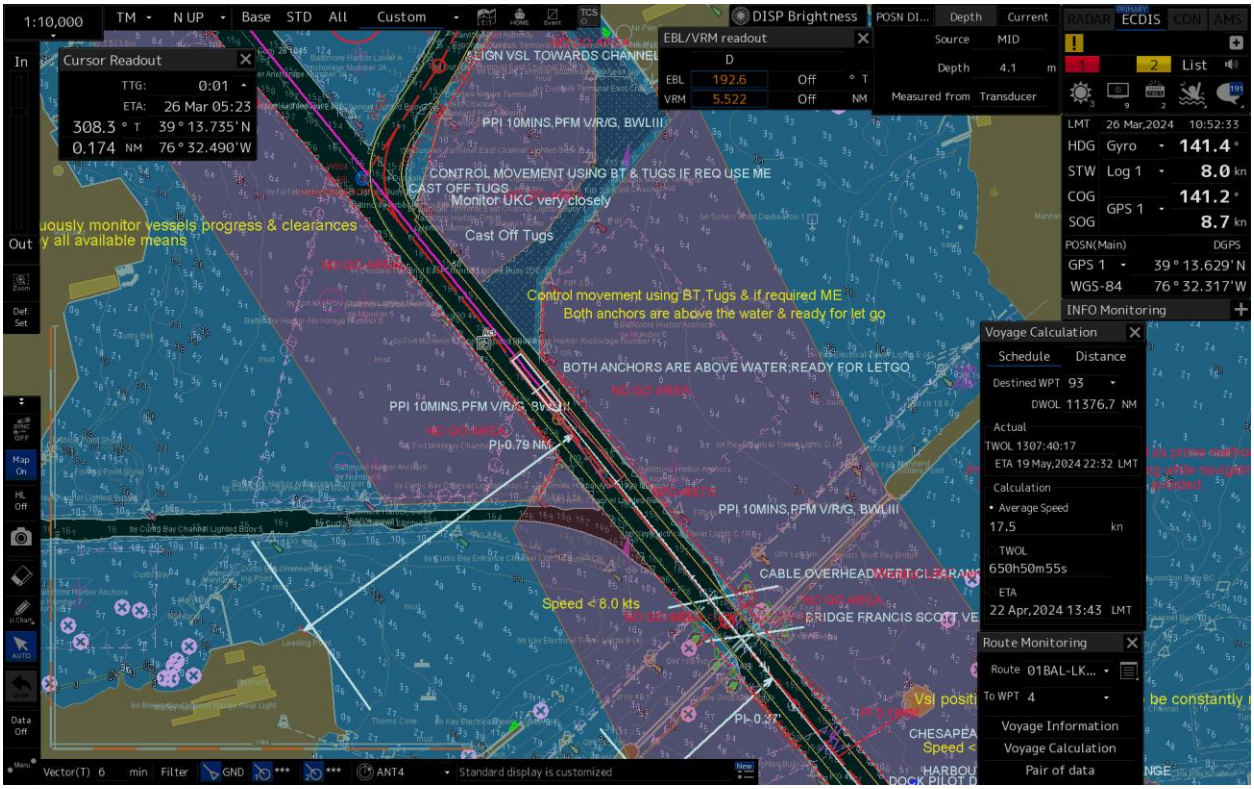

Figure 164. ECDIS display at approximately 01:23:46 EDT.

Figure 165. ECDIS display at approximately 01:23:51 EDT.

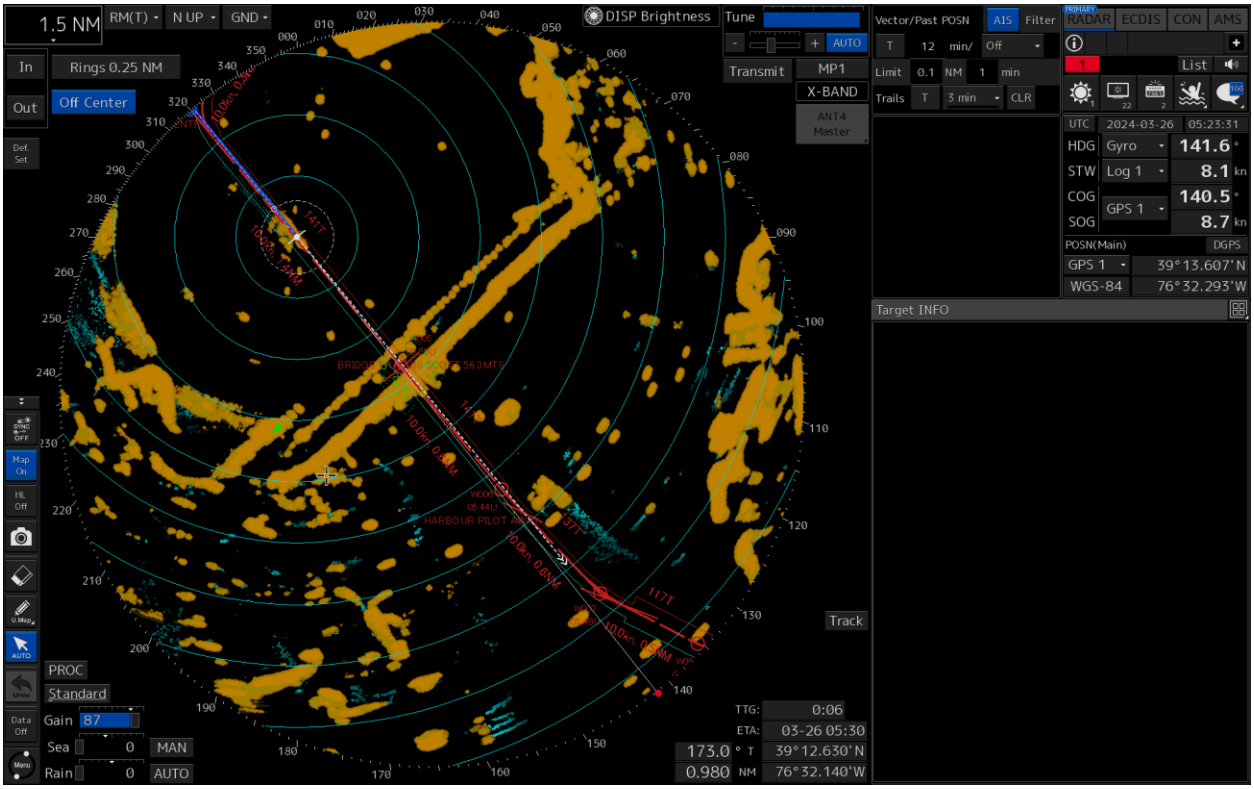

Figure 166. X-Band radar display at approximately 01:23:56 EDT.

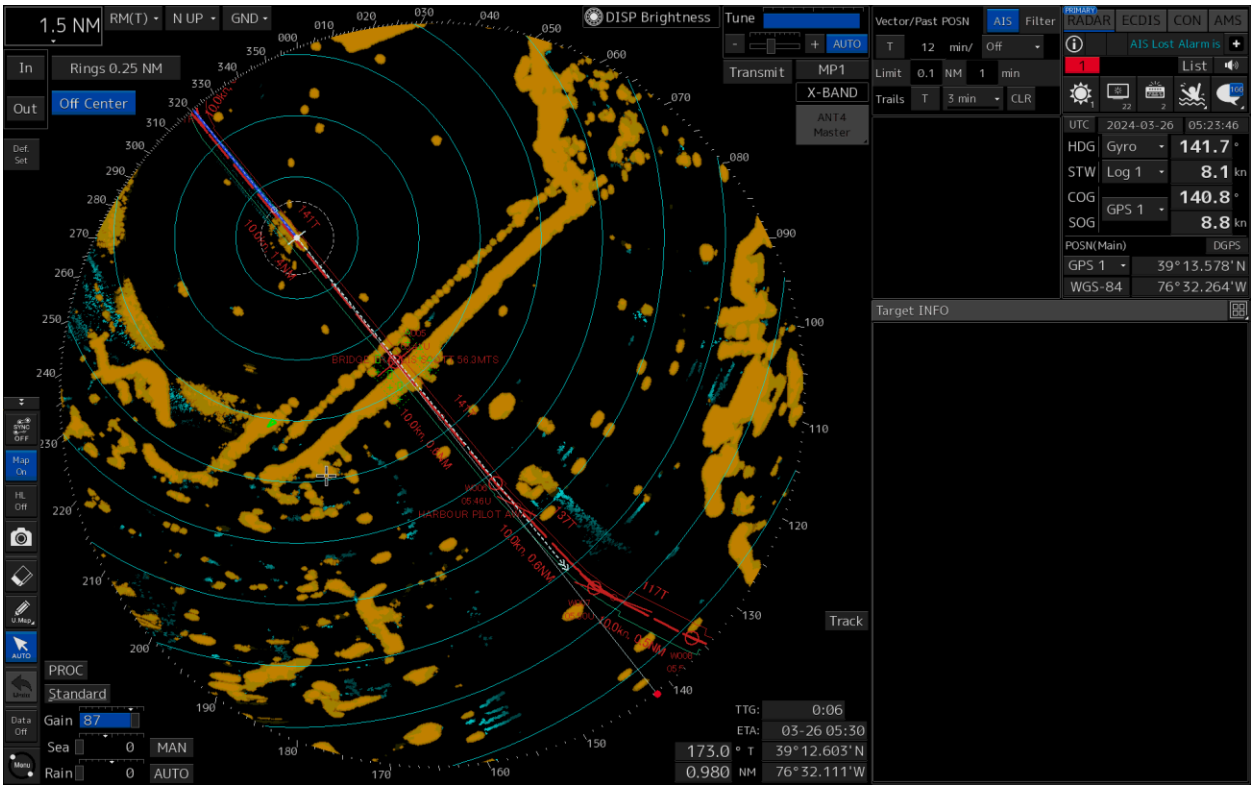

Figure 167. X-Band radar display at approximately 01:24:11 EDT.

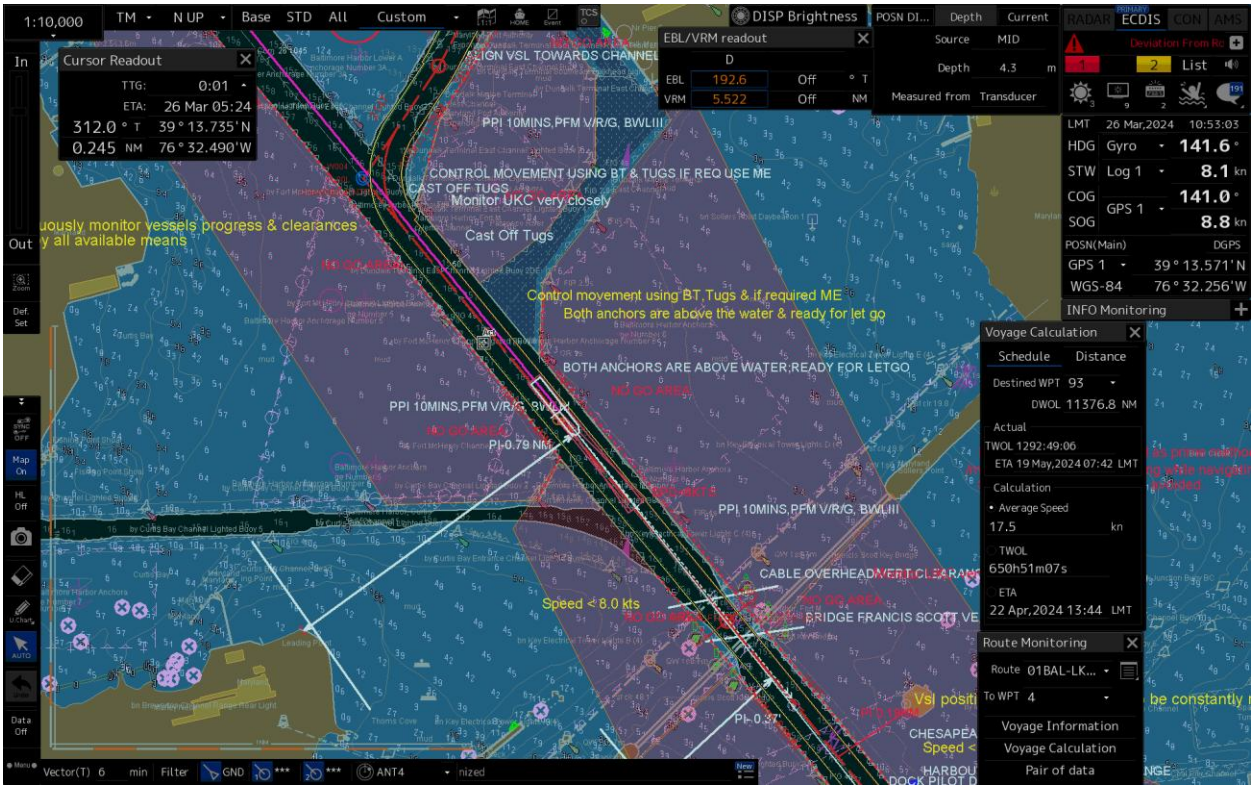

Figure 168. ECDIS display at approximately 01:24:16 EDT.

Figure 169. ECDIS display at approximately 01:24:21 EDT.

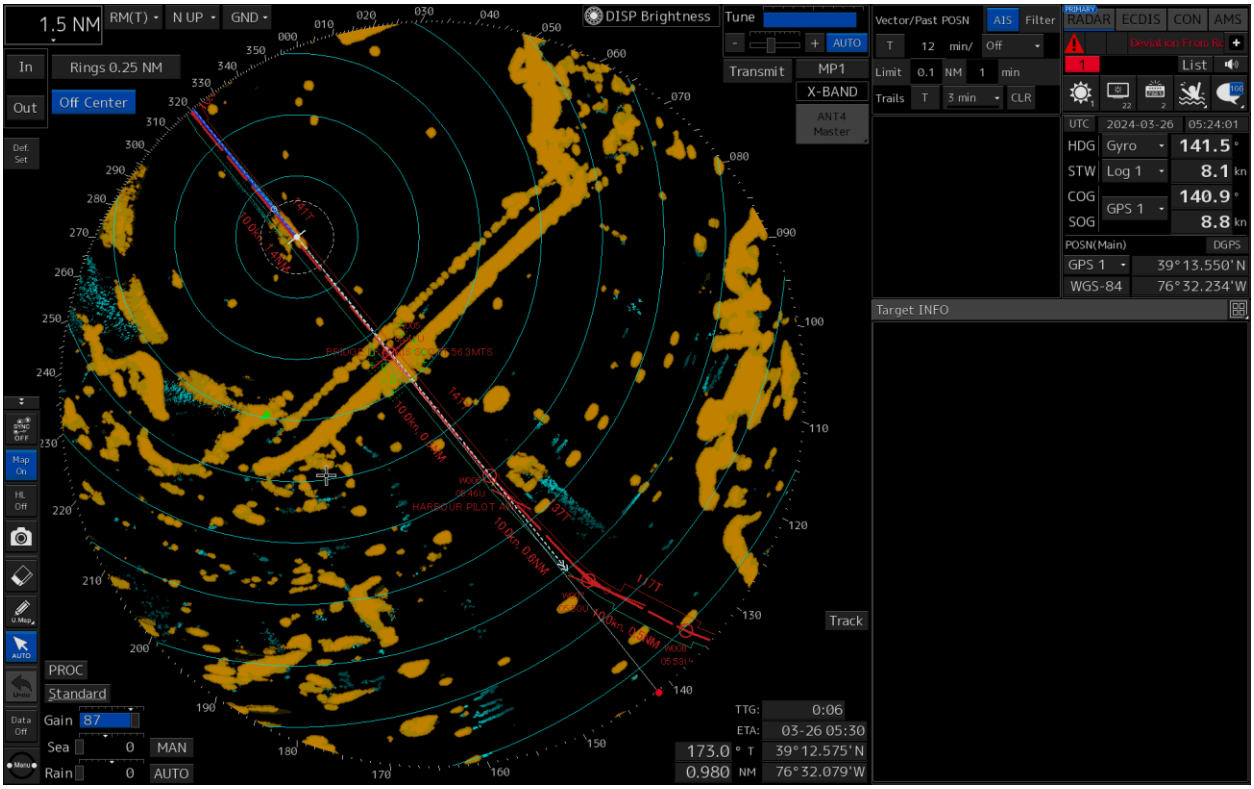

Figure 170. X-Band radar display at approximately 01:24:26 EDT.

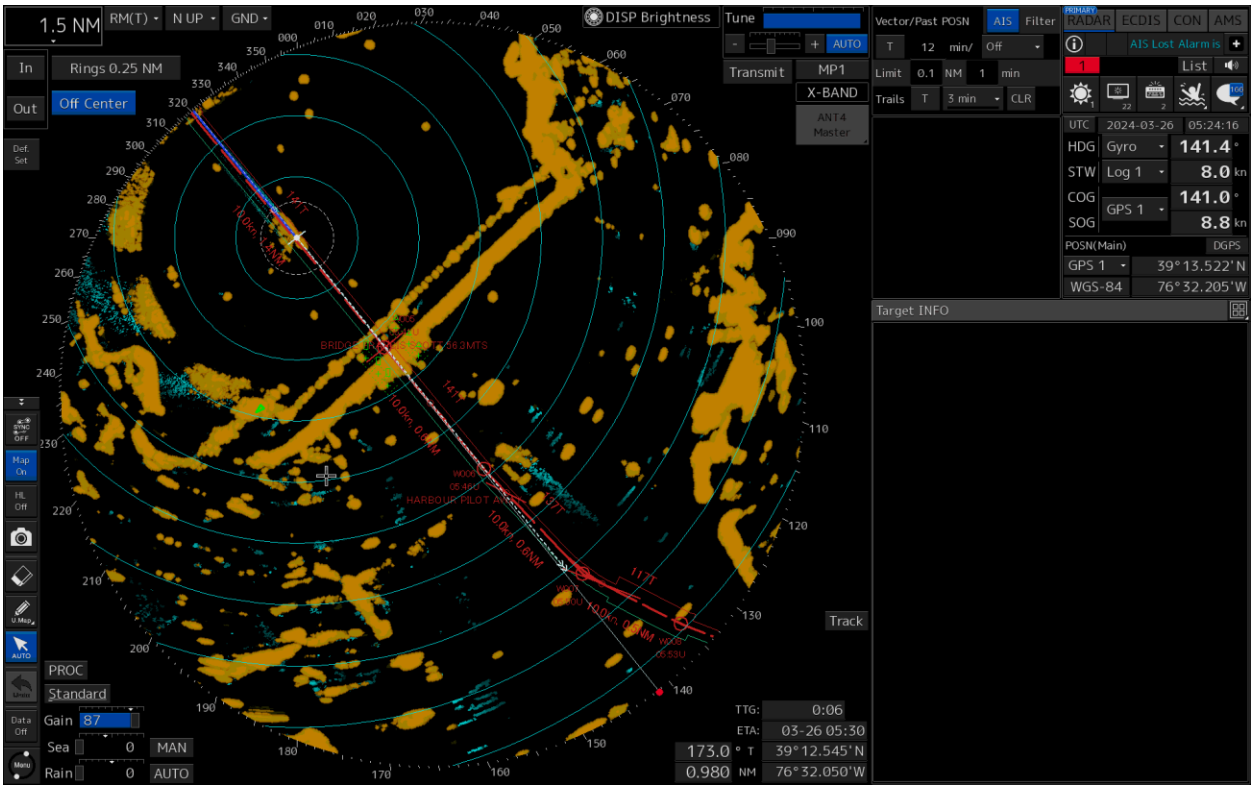

Figure 171. X-Band radar display at approximately 01:24:41 EDT.

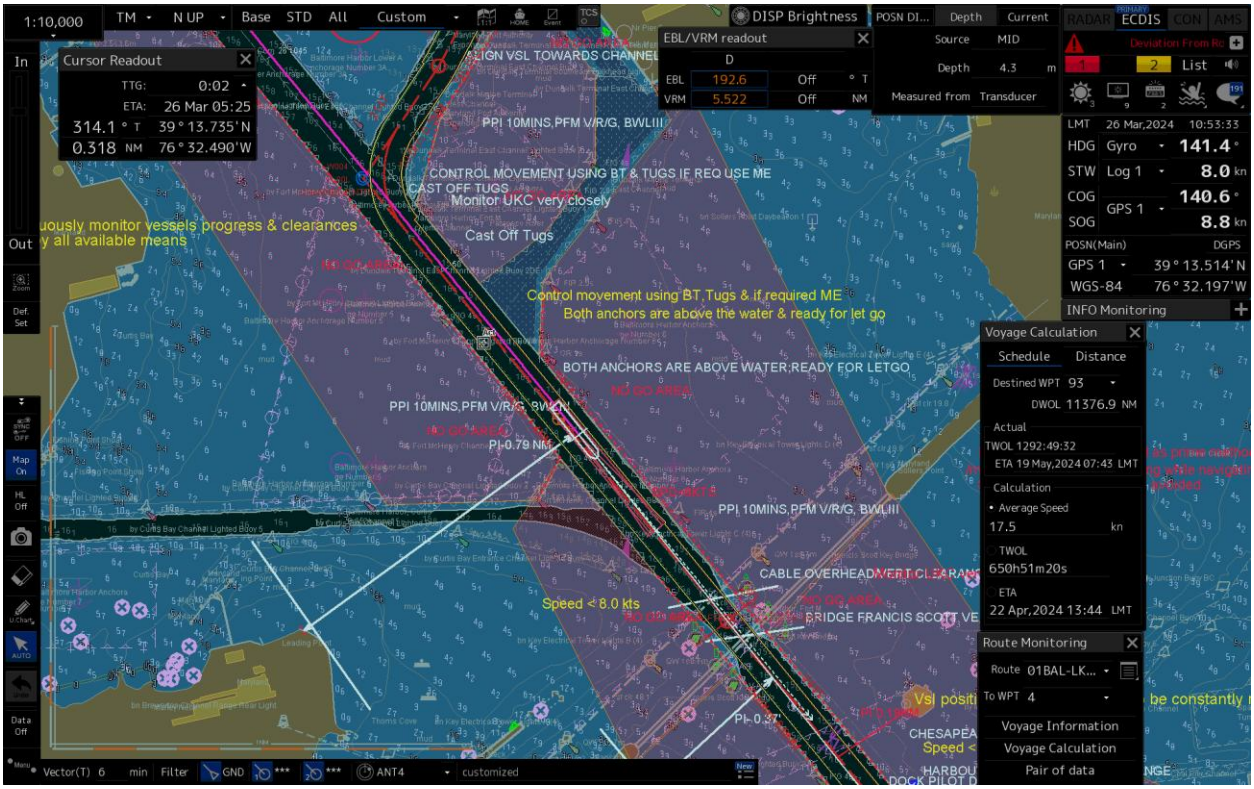

Figure 172. ECDIS display at approximately 01:24:46 EDT.

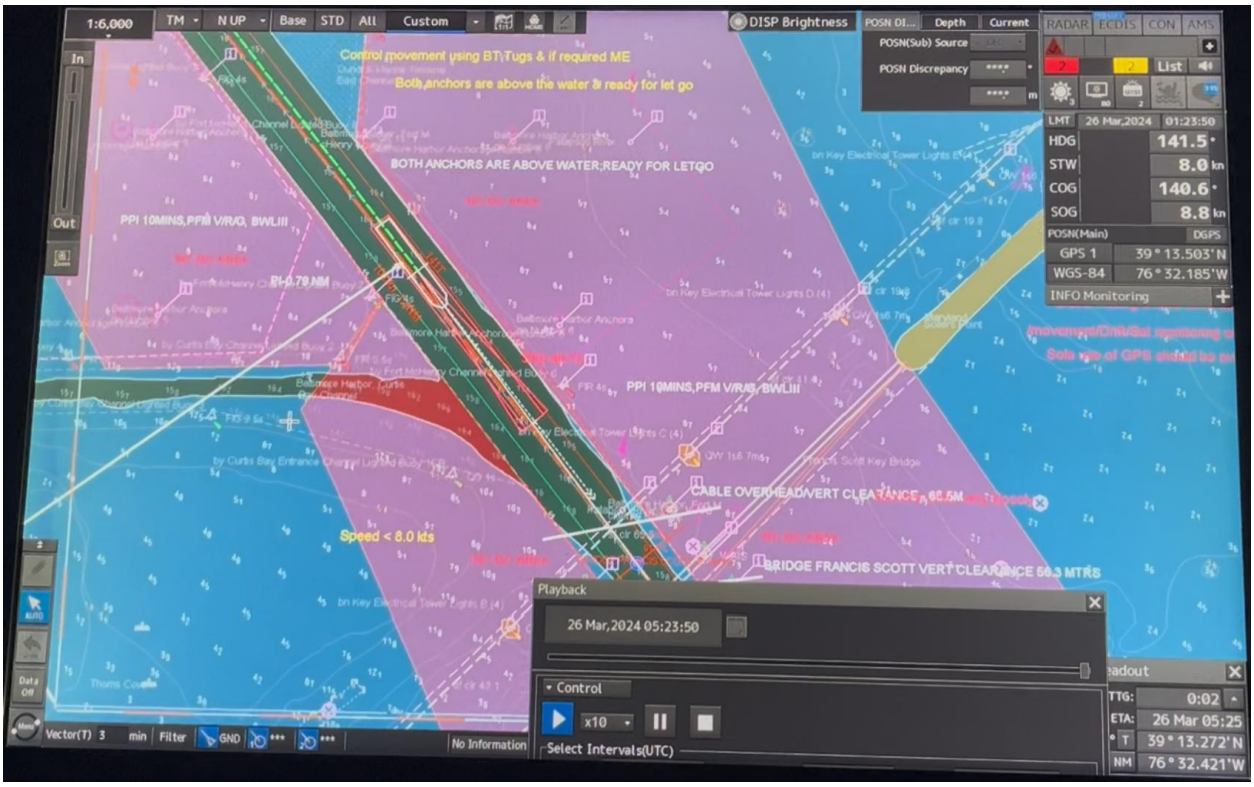

Figure 173. ECDIS playback image at approximately 01:24:51 EDT.

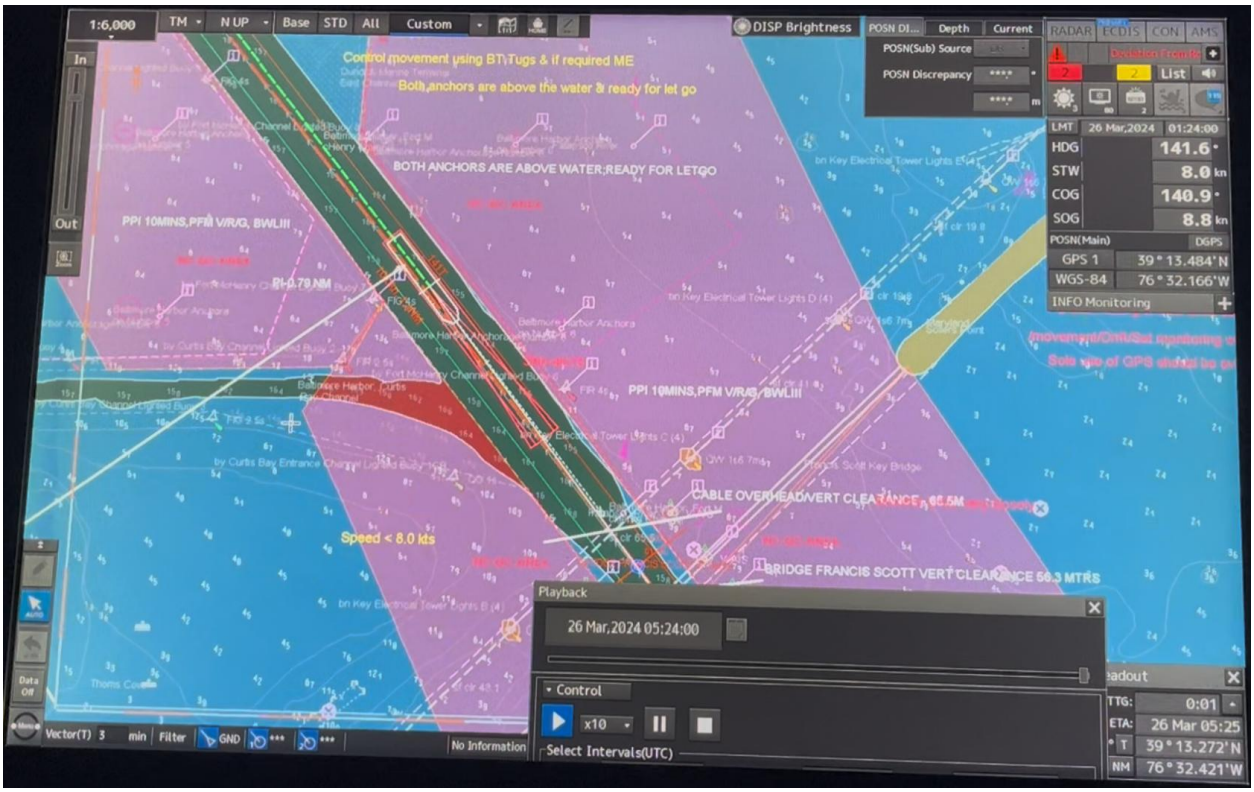

Figure 174. ECDIS playback image at approximately 01:25:01 EDT.

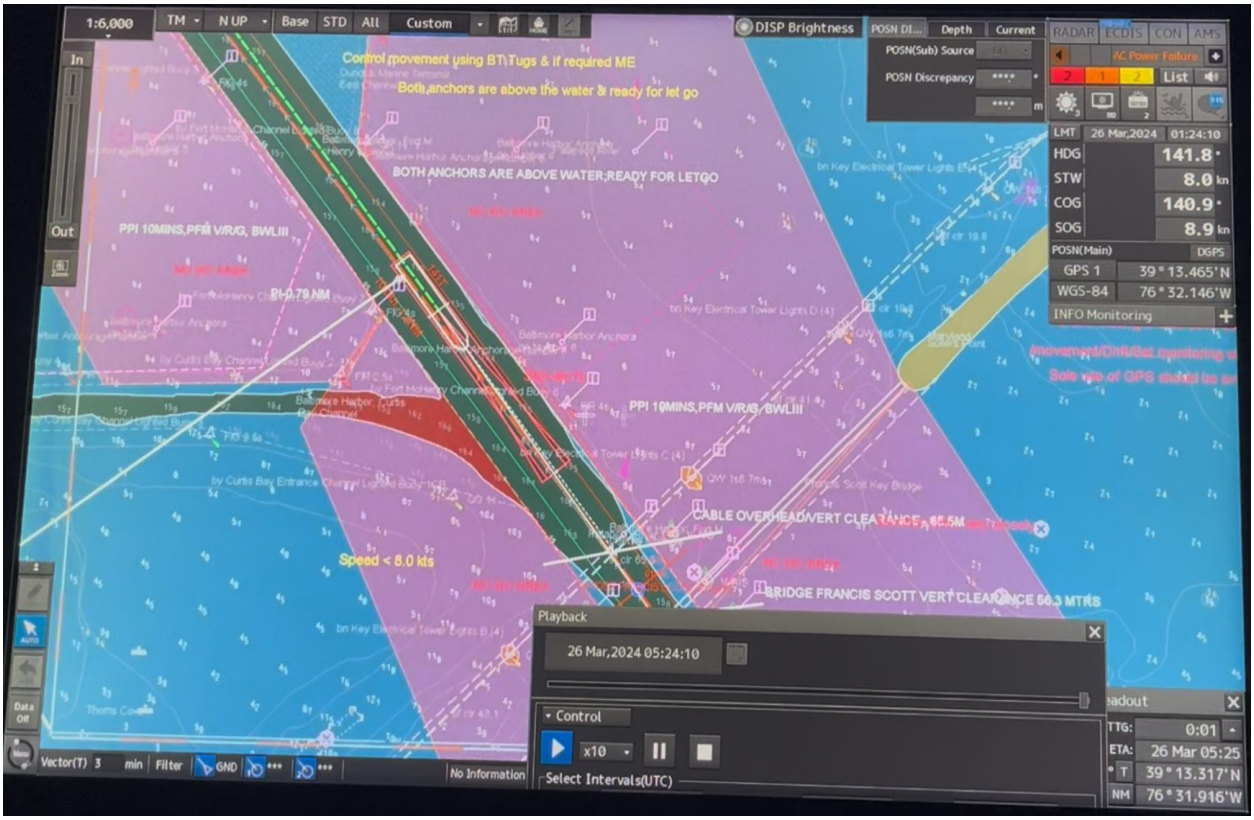

Figure 175. ECDIS playback image at approximately 01:25:11 EDT.

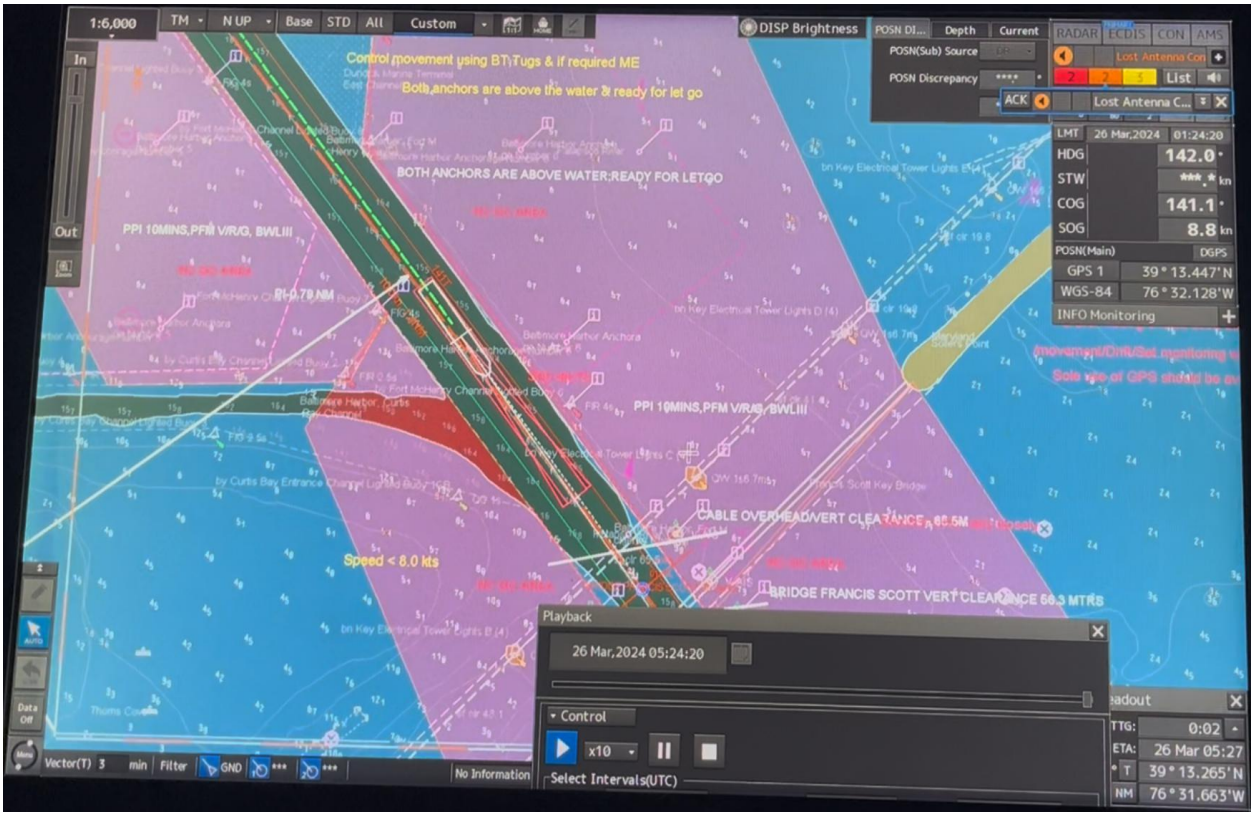

Figure 176. ECDIS playback image at approximately 01:25:21 EDT.

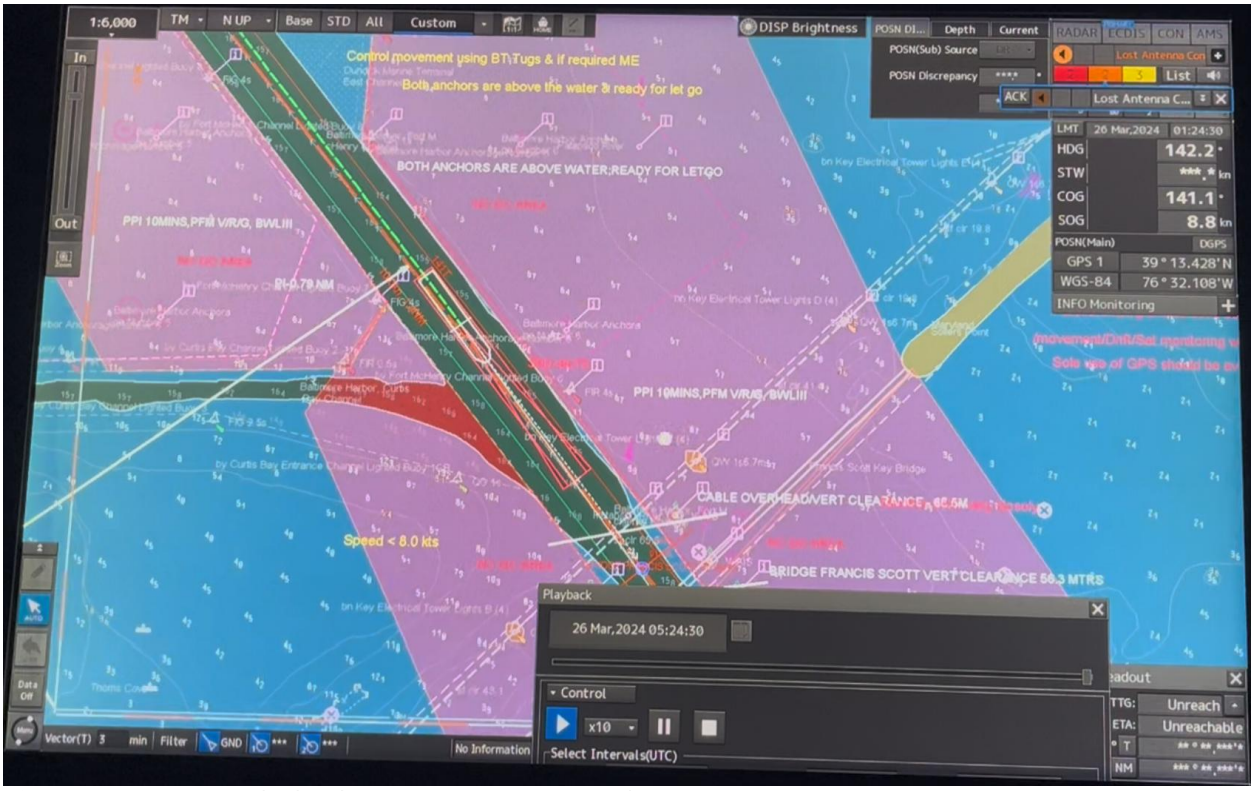

Figure 177. ECDIS playback image at approximately 01:25:31 EDT.

Figure 178. ECDIS playback image at approximately 01:25:41 EDT.

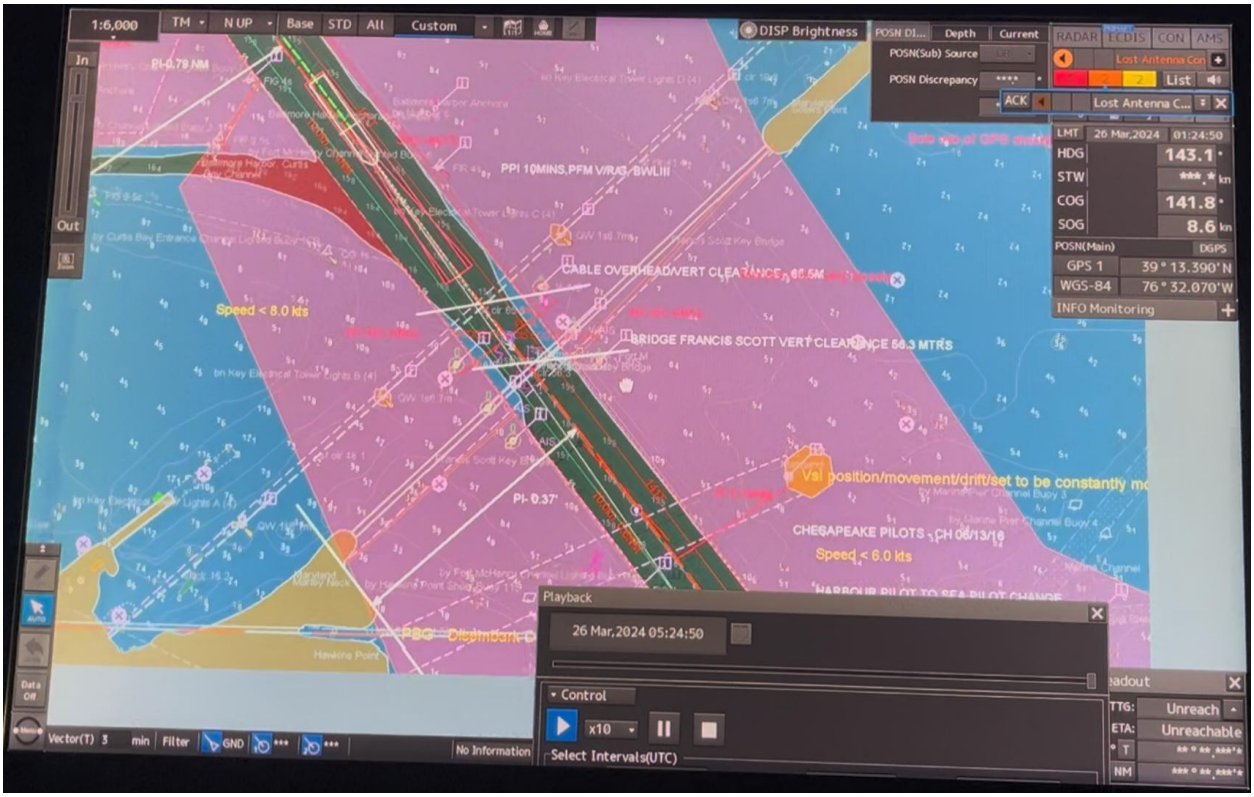

Figure 179. ECDIS playback image at approximately 01:25:51 EDT.

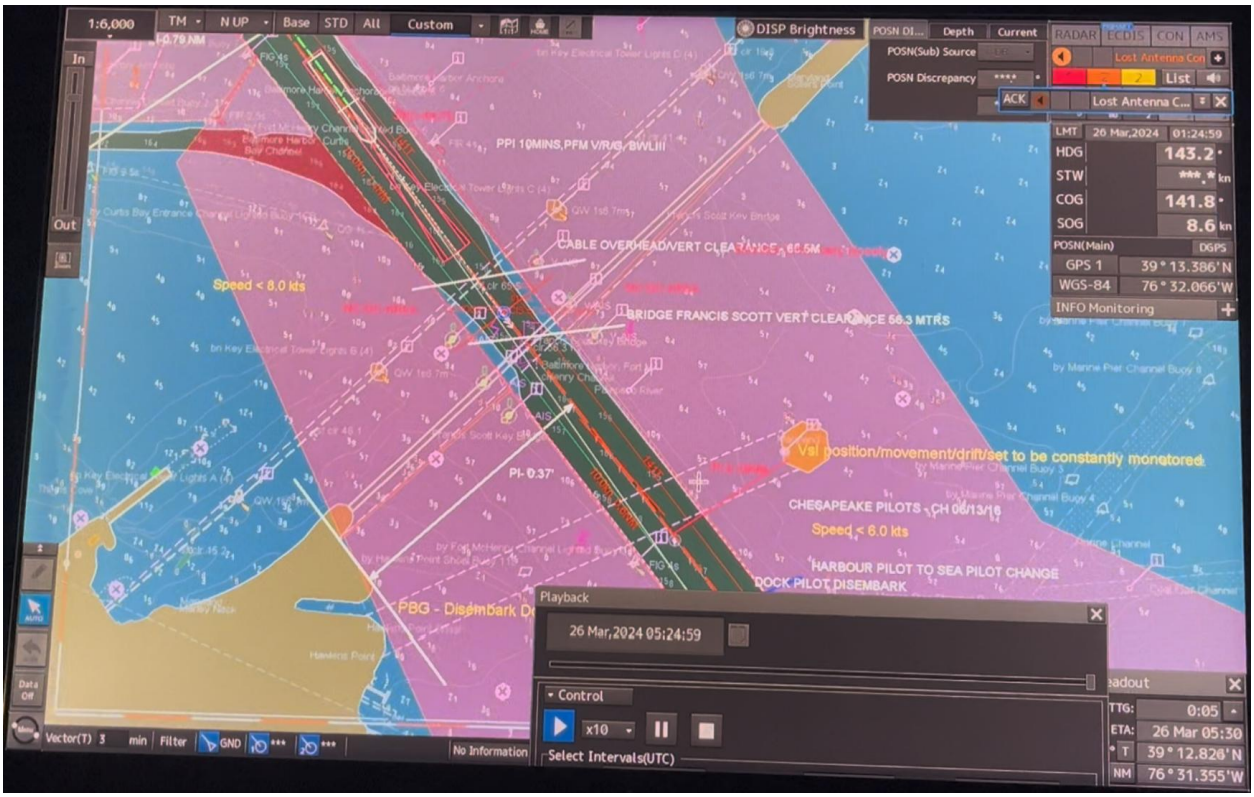

Figure 180. ECDIS playback image at approximately 01:25:53 EDT.

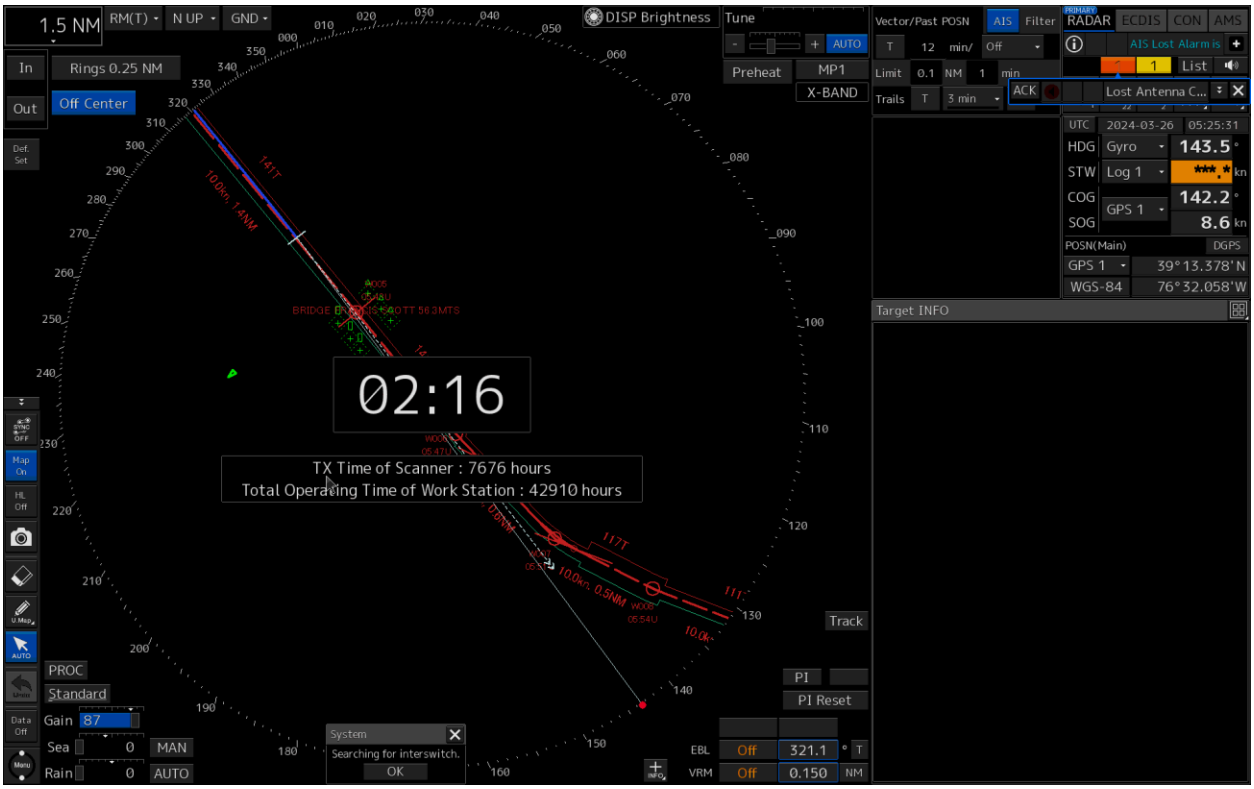

Figure 181. X-Band radar image at approximately 01:25:56 EDT.

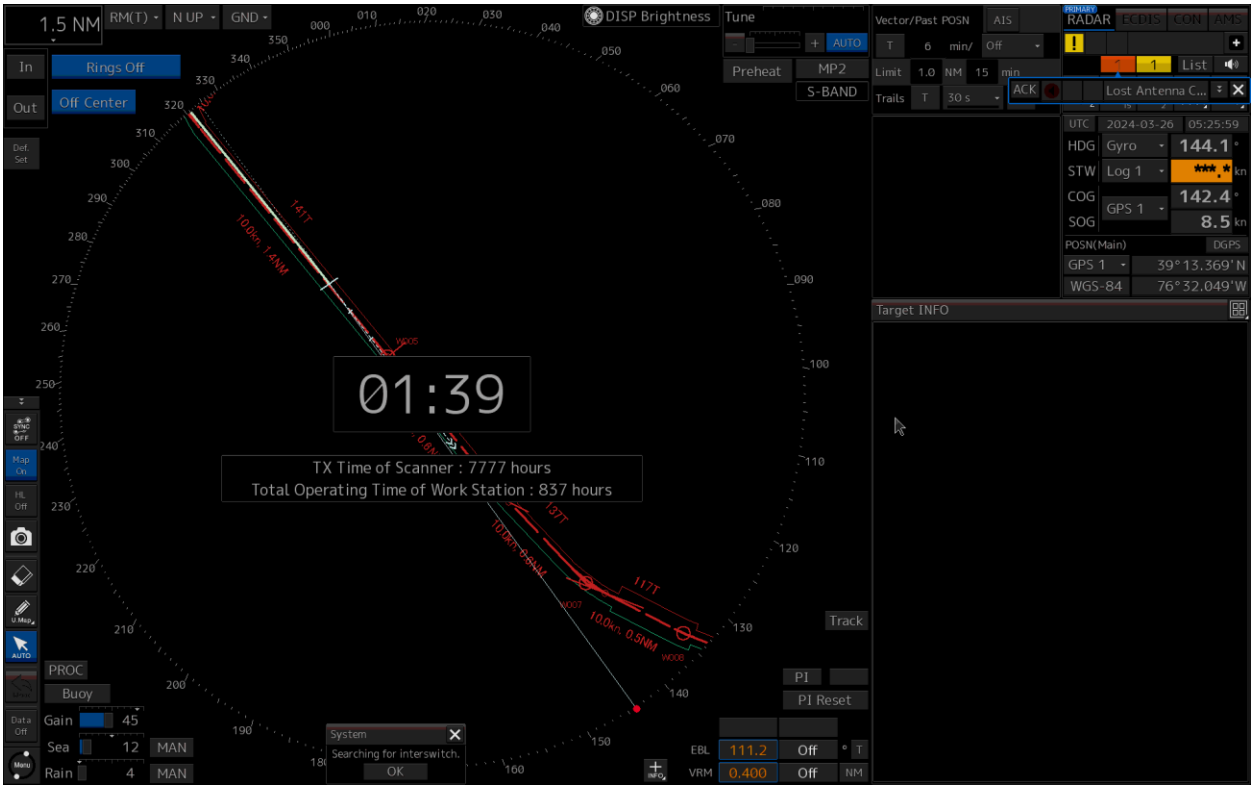

Figure 182. S-Band radar image at approximately 01:26:02 EDT.

APPENDIX A. VERIFIED AND PROVIDED PARAMETERS

This appendix describes the parameters provided and verified in this report. Table A-1 lists the parameters and source, and Table A-2 describes the unit abbreviations used in this report.

Table A-1. Verified and provided parameters.

Parameter Name	Parameter Description	Source
#GENCUR (A)	No. 1-4 Generator Engine Current	HiMAP
#GENFREQ (Hz)	No. 1-4 Generator Engine Frequency	HiMAP
#GENPF	No. 1-4 Generator Engine Power Factor	HiMAP
#GENPWR (kW)	No. 1-4 Generator Engine Power	HiMAP
#GENVOL (V)	No. 1-4 Generator Engine Voltage	HiMAP
COG (deg)	True Course Over Ground	JCY-1900, AIS
DepthRelative (ft)	Water Depth Relative to the Transducer	JCY-1900
EngineRPM (rpm)	Engine Revolutions per Minute	JCY-1900, CoCoS-EDS
HDG (deg)	True Heading	JCY-1900, AIS
Latitude (deg)	Latitude	JCY-1900
Longitude (deg)	Longitude	JCY-1900
LongGndSpd (kts)	Longitudinal Ground Speed	JCY-1900
LongWaterSpd (kts)	Longitudinal Water Speed	JCY-1900
# Steering Gear Control Power Failure	No. 1-3 Steering Gear Control Power Failure	JCY-1900, ACONIS AMS
# Steering Gear No Voltage	No. 1-3 Steering Gear No Voltage	JCY-1900, ACONIS AMS
ROT (deg/min)	Rate of Turn	JCY-1900, AIS
RPMDemand (rpm)	Engine Revolutions per Minute Demand	JCY-1900, CoCoS-EDS
RudderAngleDemand (deg)	Rudder Angle Demand	JCY-1900
RudderSensorAngle_YX (deg)	Rudder Sensor Angle, Transducer	JCY-1900
RudderSensorAngle_HTC (deg)	Rudder Sensor Angle, Heading/Track Control Data	JCY-1900
Satellites in Use	Number of Satellites in Use	JCY-1900
SOG (kts)	Speed Over Ground	JCY-1900, AIS
StrnTrnvGndSpd (kts)	Stern Transverse Ground Speed	JCY-1900
Thruster Demand ID	Thruster Demand Identification	JCY-1900
Thruster Demand Pitch Mode	Thruster Pitch Demand Mode Indicator	JCY-1900
Thruster Demand RPM Mode	Thruster RPM Demand Mode Indicator	JCY-1900
Thruster Op Location	Thruster Operating Location	JCY-1900
Thruster Pitch Demand (deg)	Thruster Pitch Demand	JCY-1900
Thruster Pitch Response (deg)	Thruster Pitch Response	JCY-1900
Thruster Response ID	Thruster Response Identification	JCY-1900
Thruster Response Pitch Mode	Thruster Pitch Response Mode Indicator	JCY-1900
Thruster Response RPM Mode	Thruster RPM Response Mode Indicator	JCY-1900
Thruster RPM Demand (RPM)	Thruster RPM Demand	JCY-1900
Thruster RPM Response (RPM)	Thruster RPM Response	JCY-1900
TrnvGndSpd (kts)	Transverse Ground Speed	JCY-1900
WindDirectRel (deg)	Relative Wind Direction	JCY-1900
WindSpdRel (kts)	Relative Wind Speed	JCY-1900

Table A-2. Unit abbreviations

Units Abbreviation	Description
A	amperes
deg	degrees
deg/min	degrees per minute
ft	feet
Hz	hertz
kts	knots
kW	kilowatt
rpm	revolutions per minute
V	volts

NOTE: For parameters with a unit description of discrete, a discrete is typically a 1-bit parameter that is either a 0 state or a 1 state where each state is uniquely defined for each parameter.