NATIONAL TRANSPORTATION SAFETY BOARD
Office of Marine Safety
Washington, D.C., 20594

April 21, 2008

DECK OPERATIONS GROUP FACTUAL REPORT
Bridge Navigation Equipment Addendum

DCA08MM004

A. ACCIDENT

Vessel:	M/V *Cosco Busan*
Date:	November 7, 2007
Time:	0830 Pacific Standard Time
Location:	Pier D, San Francisco-Oakland Bay Bridge, 37° 48.1' N, 122° 22.5'W
Owner/Operator:	Regal Stone Ltd., Fleet Management
Complement:	1 Pilot, 24 Crew.

B. DECK OPERATIONS GROUP

Rob Jones, NTSB
Group Chairman
Washington, DC

Tom Roth-Roffy, NTSB
Assistant Group Chairman (Electronic Navigation Equipment)

Deck Operations Factual Report Addendum

Bridge Electronic Navigation Equipment

1. Radar. As required by international regulations, the ship was fitted with two functionally independent radar systems.[1] The two radars were manufactured by Sperry Marine[2] and were part of the ship's Voyage Management System (VMS) (see Figure 1). The VMS also included the Electronic Chart System and the Conning Information Display (CID), discussed later in this report.[3] One radar was an x-band (3 cm), and the second radar was an s-band (10-cm). The radar information from the two radar systems could be arranged to be displayed on either of the two available displays through use of an interswitch.

   According to a Sperry Marine representative who testified at the Safety Board public hearing, the BridgeMaster E is a very common marine radar, with about 9,000 having been produced since their inception in the late 1990s. The radar was interfaced with the electronic chart in that the operator could chose to display the radar image overlaid on the chart. In addition, radar targets were displayed on the electronic chart and electronic chart voyage plan (route) could be displayed on the radar. The 3 cm radar image was captured every 15 seconds and recorded by the simplified voyage data recorder (S-VDR).[4] According to the Sperry Marine representative, the radar images captured by the VDR did not indicate that route plans were loaded and displayed on the radar. In his interview with the Safety Board the pilot stated that no course lines were drawn on the electronic chart while he was aboard:

   > … when I got on the ship, there was no course line at all on the ECDIS that I could see, but I didn't look must past the bridge, but there were no track lines on the electronic chart.[5]

   1.1. Manufacturer: Sperry Marine (A division of Northrop Grumman), Charlottesville, VA

---

[1] Carriage requirements for radar are specified in SOLAS Chapter V, Regulation 19. The regulation requires installation of a 3 cm (x-band/9 GHz) for ships of 300 gross tons and greater. As second radar (functionally independent of the first radar), (10 cm (s-band/3 GHz)) is required for ships 3000 gross tons and upwards. All ships 500 gross tons and upward are required to have an ARPA.

[2] The equipment cabinets were labeled "Litton Marine Systems," which was a division of Litton Industries. Litton Industries was acquired by Northrop Grumman in 2001.

[3] The VMS also included the Automatic Navigation and Track Keeping System (ANTS) module. According to Sperry Marine product information, the ANTS determines ship's present position, monitors advance against planned track and determines the correct heading and speed orders to keep the ship on the prescribed track. The ANTS interfaces directly with the autopilot and speed control systems. According to Sperry Marine, the integration of the ANTS to the VMS had been disabled some time before the accident.

[4] See the VDR factual report for additional information on VDR recordings.

[5] Safety Board interview of pilot on Nov 12, 2008, transcript p. 65.

1.2. Model: BridgeMaster E with automatic radar plotting aid (ARPA)

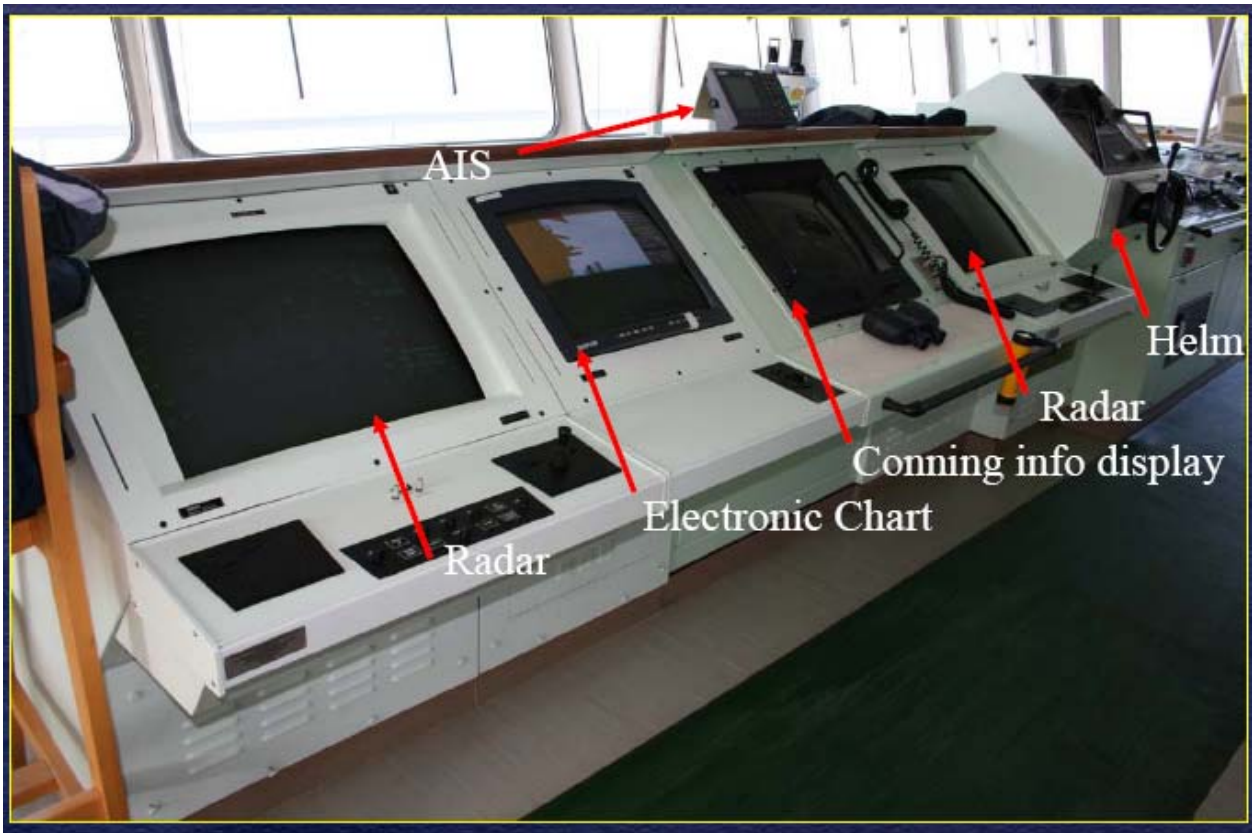

Figure 1 - Bridge Navigation Console

2. <u>The Electronic Chart System (ECS)</u>. The ECS was the second major component of the Voyage Management System (VMS). The ECS was composed of 3 components: hardware, operating software, and chart database. Sperry Marine provided the hardware and operating system software, while another company, C-Map, provided the navigation chart database. Although the ECS hardware/software system was type approved as an Electronic Chart and Information Display System (ECDIS), it was operating as an Electronic Chart System (ECDIS-like installation) because the VMS software was not configured as an ECDIS and the system was not

using certified ENC navigation charts.[6] The CM-93 chart database, provided by C-Map, did not meet international standards for ECDIS installations.[7]

2.1. ECS Hardware

2.1.1. Model: Vision 2100 ECDIS, 3-node (navigation station, planning station, and conning station).

2.1.2. Hardware first type approval as an ECDIS by DNV in 2000.

2.1.3. The hardware consisted units and of three display

2.2. VMS Software

2.2.1. Software version: VMS 5.5

2.2.2. The software was first type approved by DNV in 2002.

2.3. VMS Network. System was network connected, with data sharing between three nodes (navigation station, planning station, and conning station). All three nodes were fully independent and are able to synchronize navigational data with other nodes on the network. Each VMS retained a encrypted data log which was a history of active sensors, AIS and radar contacts, and chart usage. The data log retained at least 30-days of data.

2.4. Chart database: C-Map, version CM-93 , vector chart

3. AIS. The ship was fitted with an Automatic Identification System (AIS) as required by international regulations.[8] The AIS transmitted own ship navigation information to other ships in the area as well as Vessel Traffic Service (VTS) organizations monitoring or directing harbor traffic. International Maritime Organization (IMO) standards specify that AIS transmit the following information (Figure 1):

[6] An electronic chart system is not designed to meet the SOLAS carriage requirement for navigation charts (SOLAS Chapter V), and therefore must be used in conjunction with required paper charts. IMO has not issued standards for ECS, but the Radio Technical Commission for Maritime Services (RTCM) developed a voluntary standard for ECS. (American Practical Navigator, Chapter 14 available online at http://www.nga.mil/MSISiteContent/StaticFiles/NAV_PUBS/APN/Chapt-14.pdf)

[7] International Hydrographic Organization (IHO) standards S-57 and S-52 specifies requirements for compliant chart databases.

[8] International Maritime Organization (IMO) performance standards are specified in Maritime Safety Committee (MSC) Resolution MSC.74.(69) Annex 3, and International Electrotechnical Commission (IEC) technical and test standards are specified in IEC 61993. Carriage requirements are specified in SOLAS regulations at Chapter V Regulation 19.

6.1 The information provided by the AIS should include

.1 Static:

- IMO number (where available)
- Call sign & name
- Length and beam
- Type of ship
- Location of position-fixing antenna on the ship (aft of bow and port or starboard of centerline)

.2 Dynamic:

- Ship's position with accuracy indication and integrity status
- Time in UTC*
- Course over ground
- Speed over ground
- Heading
- Navigational status (e.g. NUC, at anchor, etc. - manual input)
- Rate of turn (where available)
- Optional - Angle of heel (where available)**
- Optional - Pitch and roll (where available)**

.3 Voyage related:

- Ship's draught
- Hazardous cargo (type)***
- Destination and ETA (at masters discretion)
- Optional - Route plan (waypoints)**

.4 Short safety-related messages

Figure 2 - AIS data required by performance standard

The static information is sent every 6 minutes and on request, and the update frequency of the dynamic data is dependent on the operational condition of the vessel as shown in Figure 3:

Type of ship	Reporting interval
Ship at anchor	3 min
Ship 0-14 knots	12 sec
Ship 0-14 knots and changing course	4 sec
Ship 14-23 knots	6 sec
Ship 14-23 knots and changing course	2 sec
Ship > 23 knots	3 sec
Ship > 23 knots and changing course	2 sec

Figure 3 – IMO performance Standard - information update frequency

4. Condition of electronic navigation equipment at the time of the accident

4.1. Radars

4.1.1. Repair history. Sperry Marine provided copies of the service records for the radars.[9] The most recent service call by Sperry Marine was on Nov 05, 2007 in the port of Long Beach. The ship had requested the assistance of Sperry Marine to repair a low video condition on the x-band (3 cm) radar. According to the service report, the 3 cm radar antenna was not rotating as a result of a loose connection to the motor and power. In addition, the service engineer found the magnetron (self excited microwave oscillator) leads inverted. According to Sperry Marine, the result of inverted leads at the magnetron would not be detrimental to the radar performance but would cause a somewhat shorter life of the magnetron. After replacing the magnetron and the modulator, the radar operation was restored to proper operation. According to the radar service history, the previous service call for the x-band radar on May 20, 2006, in Rotterdam, when the magnetron current was found to be low and the magnetron was renewed. According to the service report, the radar work normally after the repair. The s-band radar was last serviced on July 17, 2007, in Long Beach . According to the service report, this service call appears to be in follow up to an unresolved service call made in Long Beach on July 14, 2007. At that time the ship reported poor target display with the auto tune stuck in the mid position. The service report indicates the receiver was replaced to correct the auto tune problem. In addition, water intrusion was

[9] The Sperry Marine service record for the radars is entered in the Safety Board's Docket Management System (DMS) as public hearing exhibit # 42

found in the antenna array and a bad turning unit was suspected. Poor targets at greater ranges were caused by problem. Subsequent service history does not indicate if or how the bad turning unit problem was resolved. The service history indicates four "x-band" service calls and three "s-band" service reports for several other operational issues since the units were installed in December 2001.

4.1.2. Testing after accident. Several days after the accident, on November 12th, Safety Board investigators arranged for the testing of the radar systems by a Sperry Marine service engineer. Among the tests done were a qualitative evaluation of the radar picture, a test of the radars' ability to acquire and track targets, the ability to display the proper bearing and range to targets, the ability to display the RACONs (radar beacon) on San Francisco Oakland Bay Bridge, and the qualitity of the gyro heading data. In addition, the magnetron current and power supply voltages tested. According to the service engineer, the diagnostic tests were normal and the radars were operating correctly at the time of the testing.

4.1.3. Testing by California Fish and Game (DFG) investigator. On the afternoon of the accident day, an investigator (who, in his previous career was a licensed sea-going master) from DFG boarded the ship to interview the crew, calculate the amount of oil spilled, and evaluate the condition of the navigation equipment on the bridge. In his notes of his tests he wrote the following:[10]

> A survey of the bridge navigational aids and instrumentation on the bridge of *mv Cosco Busan* revealed that all the instrumentation was on, still running and operational. I tested the 2 radars and compared the VRM with the range lines in order to do a quick distance check. The radars appeared to be functioning as expected.

Figure 4 - DFG Investigator notes on radar functioning

4.2. Electronic Chart System

4.2.1. Service history. According to information provide by Sperry Marine, the VMS was last repaired on April 25, 2006, when a repaired computer was installed in the system. The computer had been previously removed during a service call on April 15, 2006, when the service engineer found VMS-3 not able to start up at all. Previous service history shows 25 service calls for a variety of software and

[10] The notes of the DFG investigator are available in the Safety Board's Docket Management System (DMS) as Exhibit # 103

hardware problems.[11] A service report dated August 15, 2003, indicates that the track steering function was disabled from the autopilot to the VMS.

4.2.2. Testing after accident. In conjunction with the requested testing of the radar systems, the Safety Board requested that Sperry Marine provide a service engineer to test the operation of the electronic chart system. According to the service report dated November 12, 2007, the correct chart was displayed by the VMS and the 3 network nodes (VM1 NAV, VM2 Conning, VM3 planning) all had good data. The service report also states that both gyro data and gps data was available and selectable, and the VMS was providing radar with good position data, and all sensors were working. The service engineer made a copy of the November 7, 2007 system data for subsequent replay. The service report indicates that the VMS was fully operational.

5. Operation of electronic navigation equipment by the crew and pilot

5.1. Radar

5.1.1. Tuning by pilot and crew.

5.1.1.1. Pilot statement. According to statements made by the accident pilot in an interview with the Safety Board, before the ship got underway he was concerned with the operation of the ship's radar units.[12] He stated that he was not satisfied with the pictures on the radar, and that he spent between 45 minutes and an hour tuning the radars, adjusting the gain and the sea clutter. He also stated that the radars would not properly acquire targets. He stated that before the ship got underway, however, on later attempts to track targets the radar, the ARPA function appeared to be working.

The pilot described his the radar adjustments made before the ship got underway as follows:

.. gain, the sea return, and I forget if they had the gain -- a lot of ships for some reason use the gain suppressor when there's not gain and quite a few foreign ships for reasons I don't understand, they have a tendency to turn the gain way up and the sea return way up, which I don't, I do it the other way. I

[11] For full details of repair history see Sperry Marine report in Safety Board Docket Management System, Exhibit # 43 and the testimony of the Sperry Marine representative at the Safety Board public hearing on April 8, 2008.

[12] Interview of pilot by Safety Board on November 12, 2007. The Safety Board has conducted only one interview of the pilot, but he has through his representative made statements to the media about his observations during the accident voyage which are consistent with the statements he made during the interview.

turn everything down. Turn the gain up until I get a picture that what I think is the best, and then if sea clutter becomes a problem, then I tune that out with the sea clutter thing, and then, and I, when I got on there, we couldn't -- this terminal, the Seventh Street Terminal, was barely visible. So I, that's when I said to the mate, I said there's a whole terminal up here. I said it's not, not even on your radar, you know. So that's when I started, this wasn't there, and was a number of things you couldn't see, and then there were other things that weren't there that you could see. So we spent quite a time on both radars tuning it to our satisfaction, to my satisfaction anyway. I assume they were satisfied with it.

5.1.1.2. VDR recording. The VDR audio transcript and the screen capture recording of the 3 cm radar image confirm the pilot's statement that adjustments were made to the radar and attempts were made to acquire and track targets.[13].

07:41:00 (UTC 14:41:00) – Radar image: gain setting being adjusted (reduced)

07:00:15 – target at approximate 289 bearing being acquired by radar operator

07:02:43 – Pilot says "see it lost it again. Shows no vector. Don't see any vector on 'em."

07:04:04 – Pilot says "the target is now right about here. So that not very encouraging if you can plot anything. I gotta be able to get in and out of here. If I can't plot anything we can't go."

07:05:08 – Pilot says "its not plotting captain, I've tried to plot this target five times, never plots. Didn't plot. That's not good for fog."

07:07:24 – Pilot says "I don't want to go out if I can't see anything. Now here's another target going outbound but -. Picture's not very good."

07:08:00 - Radar image: gain setting being adjusted (increased).

07:08:45 - Radar image: gain setting being adjusted (reduced)

---

13 According to Sperry Marine, when a change is being made to one of the adjustable settings such as gain, the setting display at the side of the radar image turns from its normal grey color to a yellow color. In addition, according to the radar operating guide (Chapter 7) a target being acquired are shown with box symbol around it, and acquired targets show dot and a speed vector.

5.1.1.3. Sperry Marine evaluation of radar operation. In the Safety Board's public hearing, the witness from Sperry Marine stated that his review of the radar images showed the operators had increased the gain setting excessively and had never turned of the sea clutter filter (it remained in "auto"). The affect of the sea filter being left in auto, according to the witness, was that the returns from the area immediately around the vessel (about 20 percent of the full range from the ship) were suppressed, and the crew adjusted the gain setting higher than they should have. The affect of the high gain setting is that the radar image is that radar returns get stronger (larger).

The witness further described the tuning as follows

> when you adjust the gain, you first start by turning the rain filter and the sea filter all the way down. You make your gain adjustments so you see a light speckle on the screen and then, if necessary, you bring your filters back up. In this case, since the system was never taken out of auto sea filter, when they were increasing the gain, they were basically kind of working against the auto setting on the sea filter.

5.1.2. Distortion of image.

5.1.2.1. Pilot statement. In the same interview, the pilot stated that as he made the turn and headed towards the bridge the radar picture on **both** radars became distorted. In the interview he stated

> "The radar picture of the bridge got distorted. It got -- wider. The bridge, the bridge got wider. The RACON never appeared. And I couldn't see the bridge piers or the buoys south of the span. I couldn't picking it up on the radar."

Under further questioning, the pilot described the distortion as follows:

> … then I -- the picture of the bridge got so bad. I mean I was amazed. It's something that I've never seen a radar do this. The bridge became about that thick on the radar. I mean it's usually a fine line.
>
> Q. I'm sorry. Again, I'd like to for the record --
>
> A. I'm sorry.
>
> Q. About three-quarters --

> A. Two inches maybe or inch and a half. Much bigger than it appears usually. To me all of a sudden the picture went to hell.

And later in the interview he again described the distortion he observed as follows:

> I mean the bridge, like I said, the bridge was -- I, you know, I don't know what you would call something like that, but the bridge was like twice as wide as it usually is, and, you know, no RACON, no towers, no buoys, nothing. So I, you know, I lost trust in it.

5.1.2.2. VDR radar image and audio recording

5.1.2.2.1. A review of the radar images captured by the VDR shows that about 08:26:29 while the ship was on a heading of about 241 and as the ship as just over .33 miles from the bridge, the radar presentation of the bridge began to widen to about 1-1/2 times its previous normal thickness. About 08:28:29 after the ship had initiated a turn to starboard and the ship was on a heading of about 285, the bridge presentation returned to normal thickness.

5.1.2.2.2. A review of the audio recorded on the bridge did not indicated that any comments were made by anyone on the bridge regarding the distortion of the bridge presentation or the abandonment of the radar in favor of the electronic chart system.

5.1.2.3. Sperry Marine interpretation of radar image and redundancy of radars

5.1.2.3.1. In the Safety Board's public hearing, when questioned about the radar image showing a widening of the bridge presentation, the radar manufacturer's representative stated

> In this image we see the ship is on its present heading of 253.8, is almost a beam of the main portion of the bridge. We're seeing the very top section of the bridge, a much stronger return. We're really, at this point, shooting our RF energy directly into the girders and everything else. We're getting a very strong return from the -- since it's a beam. We did the see the radar transponder

> in that image, also, but that was nothing unusual there that I can see.

5.1.2.3.2. When questioned about his experience with both radars failing simultaneously the Sperry Marine witness stated

> This is why we have both radars on the vessel, so that if one goes down we always should have the backup available. It's also why they inter-switch them. The inter-switch allows either antenna to be displayed on either display. So for example, if you lost one of your displays on the bridge, you could still look at either antenna or if you lost one antenna, you could see the one remaining antenna on both displays. A tremendous amount of design goes into these systems to preserve that amount of redundancy.

5.1.3. RACON.[14]

5.1.3.1. Pilot statement. According to the pilot, the RACON marking the center of the span was not visible on the radar as the ship approached the bridge. In his interview the pilot stated

> … and the RACON never showed up. I don't know if on the Notice to Mariners, I didn't see that the RACON was out or wasn't functioning but, you know, from the time we were in the bar channel, I never -- the RACON never appeared, and that's why I said that's when the whole picture of the bridge started to deteriorate.

On further questioning regarding the RACON the pilot repeated that the RACON did not appear on the radar.

> Q. At any point, did it show up on the radar?
>
> A. I didn't see it. I wasn't looking for it when we were at the dock. I mean, you know, I figured when I get close to the bridge then I'll worry about that. I was concerned with the area from here up, you know, in through here, that there was no traffic,

[14] RACONs, short for RAdar beaCON, are receiver/transmitter transponder devices used as a navigation aid, identifying landmarks or buoys on shipboard marine radar display. A RACON responds to a received radar pulse by transmitting an identifiable mark back to the radar set as a Morse code character. RACONs do not transmit continuously but have a specified on- off duty cycle so that the RACON response never completely masks an important radar contact. The normal duty cycle for U.S. RACONs installed on shore locations is for them to operate 75 percent of the time. (www.navcen.uscg.gov/marcomms/geninfo/racon.htm). A RACON was fitted at the center of the D-E span and transmitted the Morse code letter Y (dash-dash-dot-dash) when interrogated.

and, you know, that everything looked right. But I never, like I said here, I never did see -- the RACON never appeared on the radar, on either radar that I saw. Because I was going back and forth between the radars as well as the electronic chart. Because when the one, when the -- I forget which radar it was that I was looking at when the bridge -- the picture of the bridge deteriorated. I went to the other radar to see if maybe I could see the RACON or the buoy, you know, the buoy marking the tower. And on a lot of radars, you can actually see the tower. The tower will show up. And I couldn't see anything on either radar.

5.1.3.2. VDR radar image.

5.1.3.2.1. As the ship approached the bridge the 3 cm radar was set at the 1.5 mile range, and the location of the RACON at the center of the D-E span first comes into view on the radar about 08:20 hours. A review of the radar screen capture images recorded by the VDR[15] after the center of the span comes into view shows the RACON visible at the following times:

08:21:29, 08:22:14, 08:22:29, 08:23:14, 08:23:29, 08:24:14, 08:24:29, 08:25:14, 08:25:29, 08:26:14, 08:22:14, 08:27:14, 08:27:29, 08:28:14

5.2. Voyage Management System – electronic chart symbol

5.2.1. Pilot statement. According to the pilot, he questioned the master about the meaning of the symbols on the electronic chart near the delta tower. The pilot stated that he questioned the master on two occasions – first before getting underway while making adjustments to the radars, and later as the ship approached the bridge. In his interview the pilot described his questioning of the master as follows:

… while we were working with the radars, I was looking at the electronic chart, and the symbols on the chart, on the electronic chart didn't look similar to me to the symbols that are on paper charts. So I asked the Captain, where's the center of Delta Echo span on this electronic chart? So he pointed to a position on the chart, and it had two red triangles on either side of the bridge. So I said, well, what are these? And he said, oh, those are to mark the lengths for the center of the span.

[15] The VDR captured a screen image of the 3 cm radar every 15 seconds. The VDR screen capture images are available in the Safety Board's public docket.

> He told me they were the lights on the marking the -- center. You know there's lights marking the center of the span. But I had no chart that I've ever dealt with have I seen red triangles indicating day mark or something. You know, I've never seen it indicate a light. But there's an ECDIS system -- they're not, as far as I know, there are no common -- they haven't made common the symbols on the electronic chart, and certainly it isn't the same as the paper chart. I mean that electronic one, you've probably seen it, but if you look at it, it doesn't -- the symbols aren't the same as they are on this, and that's how I got misled, and the RACON never showed up.
>
> I asked the Captain to indicate to me the center of the Delta Echo span of the bridge, we were on -- looking at the -- I don't know if it's an ECDIS or an EC -- what kind it is. There's another kind. But whatever kind it was, I asked him where's the center of the bridge, and he pointed to this little dot on the bridge. And on either side of the bridge, there was a red triangle.
>
> Either side of the span. North side, south side of the point that he indicated was the center of the bridge. And since I have never seen that symbol on a chart, I asked, I said what, what does this indicate? And he said, the lights -- which they're all, you know, there's all these lights marking the center of the span. So I figured, well, I guess this machine just -- as far as I know there's no universal system for symbols for electronic charts like there are for paper charts. So, I mean as you can see on this chart, there's no red triangle. You look on any American chart anywhere, anywhere, and the only red triangle that you might see is a day mark or -- yeah. I've never seen a light indicated by a red triangle, and I don't know if you've gone out and look at the, the machine, but you could see it right on the machine.
>
> You know, and after I -- you know, I, I was in the correct position when I started to turn, and usually it goes right through the center, so I think there was -- well there definitely was confusion from when I shifted from the radar to that -- before. As I did that, the Captain was right there, and I once again said, is this the center of the span? And he assured me that that's the center of the span.

The pilot stated during the interview that he sees about 10 electronic chart systems per week as part of his piloting duties and has never seen a red triangle used on the charts. He reiterated his lack of familiarity with the red triangle symbol thusly:

I have never seen a red triangle on any piece of navigation information, electronic, paper or otherwise. Nothing that shows on this diagram, the photo they have of the electronic chart that the Coast Guard has here. I don't know if they've sent one to you or -- but I've, I've never seen that anywhere on any chart at any time. That's why I asked him, I said, what does this mean?

5.2.2. VDR audio recording. According to the pilot, the first time he questioned the master about the meaning of the red triangles was before the ship got underway. No record of this reported first questioning of the master by the pilot was recorded by the ship's VDR audio recording. However, as the ship approached the bridge, the reported second questioning of the master by the pilot was captured by the VDR audio recording and transcribed as follows:

08:21:56 Pilot: What are these ah red [unintelligible]

08:21:00 Crew: This on bridge

08:22:03 Crew: Bridge is [unintelligible]

08:22:05 Pilot: Oh, oh. I couldn't figure out what the red light red, triangle was.

Later, the after the VTS watchstanders has contacted the pilot about his intentions, pilot questioned the master as follows:

08:28:06 Pilot: This is the center of the bridge, right?

08:28:11 Crew: Yeah, yeah

08:28:12 Pilot: Yeah

5.2.3. Statement of California Department of Fish and Game (DFG) investigator. According to the interview notes of the DFG investigator (a licensed master with extensive sea experience before his present position with DFG) who interviewed the master in the afternoon of the day of the accident,

The **MASTER** showed me that there were as the 2 red marks as they appeared on the *ECDIS*. He stated that earlier the same morning, before departure, the 2 Red marks on the *ECDIS* were a point of conversation between the **PILOT** and himself. The **PILOT** asked the **MASTER** if the 2 red buoys represented the 'center' of the Bay Bridge. The **MASTER** agreed that the 2 red buoys located close to the 'D' tower were indeed the center of the Bay Bridge and answered in the affirmative.

At this point, the **MASTER** clarified that the 2 red buoys were the center of the San Francisco Bay Bridge but not the 'center of the D-E span' of the San Francisco Bay Bridge.

Figure 5 - Excerpt from typed notes of DFG investigator

5.2.4. Sperry Marine VMS data replay. After the accident the Safety Board requested that Sperry Marine provide the services of a service engineer to secure any available data from the electronic chart system. On November 12, 2008, a service engineer evaluated the functioning of the VMS and copied data from the VMS computer hard drives to 3-1/2 inch floppy disks for later replay and evaluation. Subsequently, on January 11, 2008, Safety Board investigators visited the Sperry Marine headquarters and captured images from the replay of the system data recorded by the VMS.[16] The presentation of the replayed data was based on the default settings within the VMS options and the replay chart presentation closely matched the photograph of the system taken by Coast Guard investigators on the day of the accident as well as photographs taken by Safety Board investigators several days after the accident.

According to statements by the Sperry Marine witness at the Safety Board's public hearing, it was unlikely that the ship's crew had entered electronic route plans during the accident voyage because the characteristic red tracklines did not appear on the radar screen captured by the VDR. In addition, the pilot stated in his interview with Safety Board investigators that electronic route tracklines were not visible on the electronic chart system during the accident voyage.

According to the Sperry Marine witness at the Safety Board's public hearing, the VMS had the ability to provide the operator with information about the meaning of various features displayed on the electronic chart through used of the query function. The witness described the process as follows:

[16] The images captured during the replay of the VMS recorder data are available in the Safety Board's Docket Management System, Exhibit #48

They allow for the operators to query any object on the chart and then they would be able to see whatever the chart manufacturer, in this case, Sea Map, had programmed in about that object. And they also allow the operators to really control the features displayed at any given time. There's dozens of features embedded within a vector chart. The standard ones would be the ability to show the symbology in either traditional or simplified format, the ability to control what the safe and unsafe water depths are by controlling what water's blue and what water's white on the chart, and the ability to control several layers, things like whether you have text or non for navigational aid names or whether you're seeing safety soundings.

There's actually three types of queries in the VMS software, a danger query, a chart query and a target query. In regards to a vector chart, the two queries that would come into play would either be a danger query or a chart query. The manual query is a chart query and in this case, when you're displaying a vector chart, anything on the chart, from a single depth sounding to a major navigational aid, the operator can push the button on the menu that says query, chart query, then they touch the object which they wish to query and the system will do a search in that area and bring up a list of all the vector database objects it finds within that search area. Then the operator can select the appropriate object and see whatever information the chart supplier programmed in about it. For example, if you queried a light, you'd see things like the name and the light characteristics.

5.2.5. International standards for chart symbols. Symbols for ECDIS compliant charts are specified by the International Hydrographic Organization (IHO) in a symbol library published as standard S-52[17] (Figure 5). Two libraries are available for use on ECDIS, the tranditional library and the simplified library. The traditional system symbols are similar to to those used on paper charts. On the Sperry Marine ECS, the operator can alternate between either the traditional or the simplified symbol library by The ECDIS operator can easily change between ethe Although the C-Map chart database in used on the ship was not in compliance of all requirements for

[17] A portion of IHO Publication S-52 Appendix 2 Addendum to Annex A, Part I, Users' Manual Edition 3.4 (2008) is reproduced as Exhibit #44 in the Safety Board's DMS.

certified charts, the red triangle for the buoy near the delta tower closely matched the S-52 symbol for a conical lateral buoy (Figure 6).

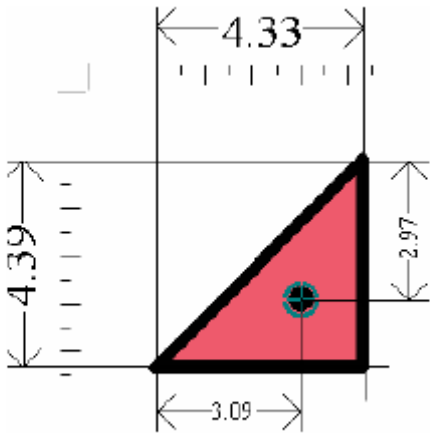

Figure 6 - IHO S-52 Symbol for conical lateral buoy

5.2.6. Photos of bouy and tower. The buoy near the D tower is shown in Figures 7 and 8.

Figure 7 - ECS data replay screen capture - 08:22 local time

Figure 8 - Photo of Delta Tower fendering system (red arrow) and Buoy (in red circle)

Figure 9 - Photo of Buoy near D Tower

6. Operator Training in use of electronic navigation equipment

6.1. Crew. The Safety Board was not able to interview the crew of the ship in order to document the training they had received in the operation of the ship's electronic navigation equipment. SOLAS requires that bridge watch officers be proficient in the use of all bridge equipment. Sperry Marine provided worldwide operator training for its navigation equipment systems but did not have records showing that any of the deck officers on the ship had received training provided by the company.[18] Fleet Management could not provide information about the training in ECDIS or electronic chart system the deck officers might have received.

6.2. Pilot. In his interview with the Safety Board,[19] the pilot stated that he has received training in simulators every three years (most recently at MITAGS near Baltimore), and man-in-model ship handling (most recently in Port Revel, France) every five years.

6.3. San Francisco Board of Pilot Commissioners. According to information provided by the California Pilot Commission, pilots are required to attend two specified courses on a recurrent basis. The "3-year course" was seven days in length, and was required of all pilots every 3 years. The accident pilot last received this training in June 2005. The training course provided to the San Francisco pilots was last conducted by the Maritime Institute of Technology & Graduate Studies

[18] Statement of Sperry Marine witness at Safety Board' public hearing on April 8, 2008 (hearing transcript p. 54).
[19] See transcript of Safety Board interview of pilot on Nov 11, 2008.

(MITAGS), and previous two training sessions were conducted by Marine Safety International and California Maritime Academy. The "5-year course" is manned model ship handling, and is required of all pilots every 5 years. The accident pilot last attended ship handling training at Port Revel,[20] France in August 2003. Previously he had attended ship handling training in Poland in August 1993 and July 1998.

6.3.1. According to the MITAGS "course framework" document provided to the Safety Board by the San Francisco Board of Pilot Commissioners, the scope of the 7-day "three year course" provided in 2005 was:

> This training program is designed to afford pilots an opportunity to gain knowledge and understanding of the principles and procedures of Azipod and Kamewa systems, Advances in Electronic Navigation, Emergency Medical Response and Emergency Shiphandling and Bridge Resource Management. This course is designed as a modular course.

The "advances in electronic navigation" module of course had the following scope:

> This training program is designed to afford pilots an opportunity to gain basic knowledge and understanding of the principals and procedures of Electronic Charting Display and Information Systems (ECDIS), Integrated Bridge Systems (IBSs) and Automatic Identification Systems (AIS). The program has been designed using the guidelines provided in the International Maritime Organization's (IMO) Model Course 1.27 for ECDIS. The AIS portion of the seminar has been developed using manufactures and government technical data. Practical applications ("hands-on" training) can be provided through the use of MITAGS simulator systems.

6.4. International standards for pilots. In 2004, the International Maritime Organization (IMO) developed "recommendations on training and certification and operational procedures for maritime pilots" and published this guidance in IMO Resolution A.960(23).

[20] Information on the shiphandling training facility can be found at http://www.portrevel.com/

Thomas K. Roth-Roffy, P.E.
Accident Investigator