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Future Voyage Data Recorder Based on Multi-Sensors and Human Machine Interface for Marine Accident

I. Morsi [1], M. S. Zaghloul[2], N.Essam[3]

[1,2,3]Arab Academy for Science, Technology, and Maritime Transport,
Electronic and Communication Department, P.O.1029, Alex, Egypt,
(E-mail: egedm@yahoo.com)
(E-mail: dr_mszaghloul@yahoo.com)

Abstract: Voyage data recorders (VDR) enable accident investigators to review procedures and instructions before an incident and help to identify the cause of any accident. The Future data recording should be capable of recording data audio and video during day and night. The recording should be of high integrity, digital as well as independent of ship supplies. Voyage data recorder, popular name black- box, is used for recording all kinds of navigation information. VDR is a data recording system designed for all vessels required to comply with the International Maritime Organization IMO's and International Convention safety of life at sea SOLAS requirements (IMO). Data from various sensors on board the vessel is collected, digitized, compressed and then stored in an externally mounted protective storage unit. The protective storage unit is a tamper-proof unit designed to with stand the extreme shock impact, pressure and heat, which could be associated with a marine incident (fire, explosion, collision, sinking, etc). This research realizes the importance of obtaining these stored data for accident analysis. This paper considers a real case accident, by downloading and replaying the data of real black box for a sunken ship in the red sea. Eventually, video recorded data of the accident will be more helpful to the investigation.

Index Terms- IMO- SOLAS- VDR- SIGNAL PROCESSING- SENSORS

1. INTRODUCTION

In 1980 the passenger ship ESTONIA sank with losses of more than 900 lives.

In 1990, the international maritime organization (IMO)developed specifications for (VDR) , which would record and store data from shipboard sensors and systems as well as voice recordings from the bridge and VHF radio communications for retrieval after an incident at sea [1].

In 2005, the IMO added requirements for a simplified VDR (S-VDR) to interface the existing analog sensor on the older ships with VDR or S-VDR which is designed to record and store information about the ship's position , movement , and physical status .All the data must be stored automatically in an approved protective capsule[2]. Passenger ships and ships with 3,000 or more gross tonnage built after June 31,2002 , must have a voyage data recorder that records a minimum of 12 hours of data , including the ship's position , speed , and heading [3] [4]. The VDR collects data from GPS, speed log, gyro compass, radar, anemometer, echo sounder, bridge audio, VHF communications, hull openings, rudder, autopilot, engine / propeller and thrusters in order to store it in an external crash survival module (CSM). With its space saving modular design it is suitable to implement the VDR for all classes of vessels including high speed ferries.

The protective storage unit as shown in fig .1 may be in a retrievable fixed unit or free float unit (or combined with EPIRB).Consequently if a ship sinks, the last 12 to 18 hours of stored data in the protected unit can be recovered and replayed by the authorities or ship owners for incident investigation. The primary purpose of the VDR is for accident investigation after the fact. However some researches call it voyage event recorder (VER). Another usage of recorded data is for preventive maintenance, performance efficiency, monitoring heavy weather damage analysis, accident avoidance, and training purpose to improve safety and reduce running cost as well as protect ships from piracy. Simplified Voyage Data Recorder (S-VDR), requirements of IMO Performance is Standard MSC.163 (78) [5].

2. INFORMATION RECORDED IN THE VDR

The information recorded in the unit which is sometimes called black box for ship, the typical configuration is shown in fig .1 includes the following information:- Date and time, are obtained from an external Global Positioning System (GPS) navigator referenced to UTC. Time information is recorded at intervals of 1s. Latitude, longitude and datum are obtained from a GPS navigator, Loran-C receiver or other EPFS or INS available on standard digital interface. The source of data is identifiable on playback. As shown in equation 1

$$P_{ji} = [(x_i - x_j)^2 + (y_i - y_j)^2 + (z_i - z_j)^2]^{1/2} \quad (1)$$

Where P: geometric range x_i, y_i, z_i are coordinates of satellite I, x_j, y_j, z_j are coordinates of site J.
Speed, whether through the water (STW) or speed over the ground (SOG) is recorded at intervals of 1 s, with resolution 0.1 knot. Heading (true, magnetic), is recorded at intervals of 1 s to a resolution of 0.1°. The data is labeled G (gyrocompass), GPS, GLONASS, MAG. Depth (echo sounder), under keel up to a resolution of 0.1 m as available on the ship is recorded, and the depth is calculated as shown in equation 2

$$R=v \times t/2 \quad (2)$$

Where R= range, v =acoustic velocity in water , v =1500m/s, t =time in seconds
Alarms, the status of all IMO mandatory alarms are recorded individually with ID number and time stamp. Audible alarms from the alarm units are stored simultaneously by the bridge audio microphones. Rudder order and response angles are recorded up to a resolution of 1° as available on the ship. Engine order/response, The Data Control Unit (DCU) obtains the engine order and response from the engine telegraph or direct engine control. The signal level is normally 0-10 V. The engine parameters with shaft revolution and ahead/astern indicators are recorded to a resolution of 1 rpm. Hull openings, watertight doors, Inputs digital or RS-422 serial can be connected individually. The data is received at intervals of 1s and stored with time stamps. Accelerations and hull stresses send signals to the DCU from appropriate monitoring devices as shown in equation 3

$$G=1+2\mu \quad (3)$$

Where G is strain gauge factor= $(\Delta r/r)/(\Delta l/l)$, μ is Poisson's ratio= $(\Delta d/d)/(\Delta l/l)$, r is the radius, l is the length. The inputs are recorded individually and stored with time stamps. Wind speed and direction, The DCU obtains the signal from appropriate wind speed and direction sensor. The inputs are recorded individually and stored with time stamps. VDR alarm output, There is no requirement for the S-VDR to send alarm messages. Radar data, Radar image including range rings, EBLs, VRMs, plotting symbols, radar maps, parts of SENC, voyage plan, and other essential navigational indications, are recorded in. One complete picture frame is captured at intervals 15 s, radar range is shown in equation 4

$$R= [P_t.\ G_t.\ \sigma.\ A_e / (4\pi)\ 2.\ P_r]^{1/4} \quad (4)$$

Where R is range, P_t: transmitted power, σ is cross sectional area, G_t is gain of antenna, A_e is Aperture radar, P_r is received power.

Bridge audio; Up to six microphones are supplied as standard to record conversation at conning station.

The microphones are labeled Mic1, Mic2, etc. Microphone captures conversation in the bridge, audio signals from equipment and sound from machinery. The microphone picks up audio signals ranging from 150 to 6000 Hz. Communications audio, A maximum of two VHF communications are recorded for both transmitted and received audio signals. The VHF radio connections are labeled VHF1 and VHF2 [6].

Fig. 1 VDR Data Recorded

3. VDR PROPLEMS AND FUTURE DIRECTION

The preset VDR suffers from too little time of recording, therefore, insufficient details force the user to ask questions. Data being lost or not recorded happens as a result of high intensity impacts and fire damage recording. New technology takes over, such as, digital messaging to the pilot replacing speech. Power fails, recording fails. The future directions are digital recording, improved survivability, and Power supply independent of the ship. Video recording is necessary by using video and IR camera to get all the available information [7].The video recording will allow simplified investigation, provide the final evidence, live video pictures from external cameras, available in the bridge would allow proper assessment of the situation. Thus, this data will provide the crew with an external view of the ship, enabling them to assess the nature and extent of external damages and fires. Adding to that, the recording of the video in the bridge will allow viewing of the captain or who is in control, monitor controls and if they are obscured. Checking instruments if they are in complete function, graphics, or even not trying to read the text or data [8].

Fig. 2 Video Image Capture

Connection as shown in fig. 2 will allow simplified investigation, provide the final evidence, live video pictures from external cameras, available in the bridge. It is necessary as well to backup real time information from an automation system or e.g. a radar display. These combinations with a high quality video source like Unigraf VTG video test pattern card source [9]. Medium Size memory for uncompressed data is 200 KB per picture, and compressed data is 15 KB per picture.

4. Replay Software Based on Case Study

The capsule has 5 P.C.B. cards inside; the first three cards are storage media type MOSFET for digital data storage. The capacity of the memory is 3x0.5 M bite, and these cards have serial numbers 345,346,347.

The card number is a control card and has the software that ensures complete retrieval and display of all recorded data. The fifth card is used for temperature registration. With a friendly human-machine interface, this software is easy to use and install. The online replay function monitor the real-time operating status of the relevant devices in the bridge. The data of the portable document compressed (PDC) is downloaded and replayed to investigate the incidents and to analyze the functioning monitor. The digital extracted data is in the form of sequence number, time, and data in 2 k packets. The sequence number consist of 32 bit (4x8 in hex decimal), the time consist of 32 bit(4x8 in hex decimal), the data consist of 8 bits and could be (video, audio, or instrument like GPS).All the previous data is in hexadecimal format. The total time of recording in this case is about 17 hours. The start time of the record is 8:11:13 at 2nd of Feb. 2006 to 1:33:13at 3rd of Feb. 2006 [10].

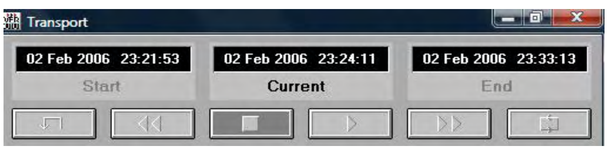

Fig. 3 Replay Control Bar

5. MONITORED DATA

The extracted digital data is collected in 50 files each file covers a period of time. The files are transferred from hexadecimal to binary, then this data is transferred to audio and video data using software [C:/CPM RECOV>d2 record] offered by Broad gate company .The output data is recorded using the monitor panel as shown in fig.3, The output can be any combination as shown in fig.4 chosen from the list. RADAR picture, GPS indicates date and time: Referenced to UTC with an indication of the source, the source is the GPS, Ship's position: in latitude (LAT) and longitude (LON) with the datum used. Speed: Through water or speed over ground as shown in fig.5. Bridge audio includes bridge wings, VHF radio communications as shown fig.6. Depth, helm command/rudder response, thruster demand/achieved, engines, alarms, hull opening and doors as shown in fig. 7. 61162 data, speed, course as shown in fig. 8. Longitudinal speed, wind speed, wind direction, heading as shown in fig 8.

Water temperature, rate of turn, commanded heading, set, drift, speed (km/h), also a serial of data format as shown in fig 9 can be obtained.

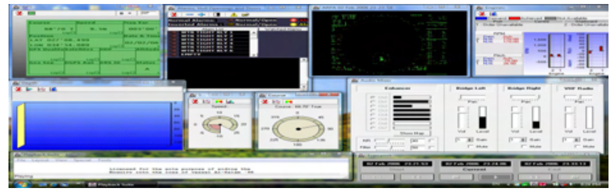

Fig. 4 Monitored output data format

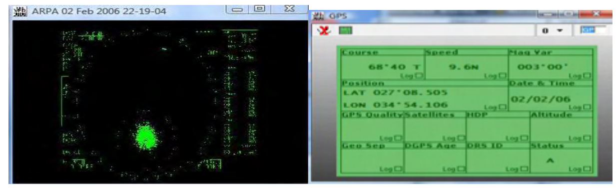

Fig. 5 Zoomed Radar Image or RADAR and GPS Image As Displayed

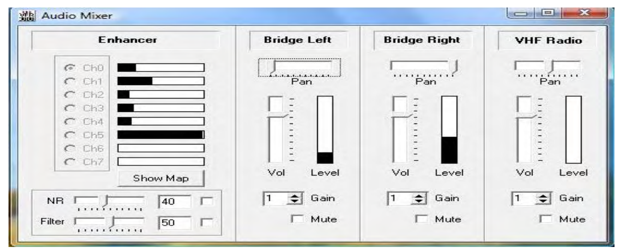

Fig.6 Bridge Audio - Including Bridge Wings, and VHF Radio Communications

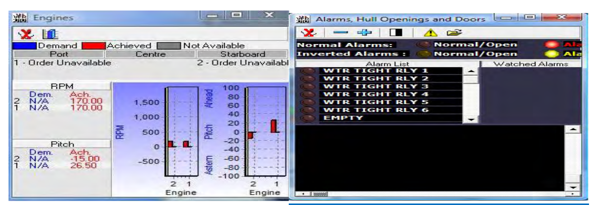

Fig. 7 Machine Engines status and Alarms, Hull openings and doors

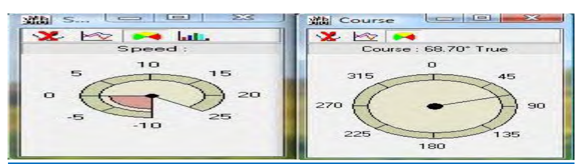

Fig. 8 Speed and course indicator

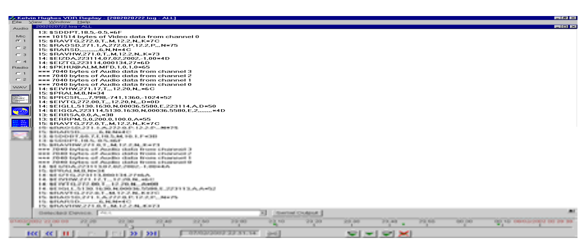

Fig. 9 Serial Data Display

6. RESULTS AND OUTPUTS

From the extracted data we demonstrate some of obtained critical data:-

FIRE: - the recorded speed 11 knots
Time of fire 9:.9:59 Date 2-2-2006
LAT 027^{o} $19^{/}$ $976^{//}$ LON 035^{o} $10^{/}$ $584^{//}$
SENDING STRESS: - the recorded speed 6 knots
Time of stress 1:30:29AM Date 3-2-2006
LAT 027^{o} $08^{/}$ $940^{//}$ LON 034^{o} $54^{/}$ $945^{//}$
SUNK: - the recorded speed 9.4 knots, slant 25, course 72^{o} $10^{/}$
Time of Sunken 1:33:13AM Date 3-2-2006
LAT 027^{o} $08^{/}$ $391^{//}$ LON 034^{o} $53^{/}$ $725^{//}$

7. Software

In this research software is developed to enhance the best use of the VDR. This software uses visual basic 6.0, and consists of VDR home page .To login the system you enter password as shown in fig. 10

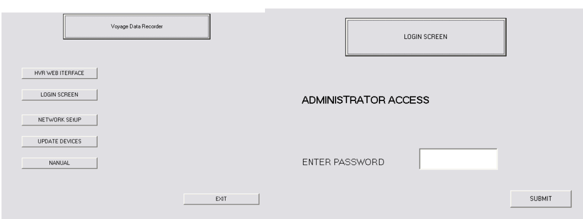

Fig. 10 Sample screen shot of the VDR home

System includes network setup page that has current volume and new volume as shown in fig .10 and fig .11.

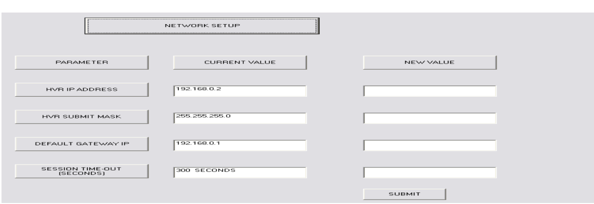

Fig. 11 Sample screen shot of the VDR network setup page

In this system it has VDR device update page that updates device allocations and stream names as shown in fig. 12

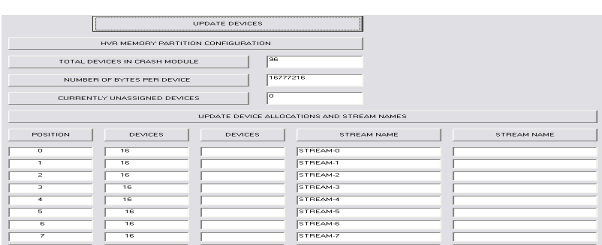

Fig. 12 Sample screen shot of the VDR device update page

The software has a system configuration, operation, operation procedure, and operation in remote alarm panel, removing VDR and how to release DRU. It includes ;1-maintenance (annual refraction , cleaning , software maintenance , software list , checking software , version of system program , checking of software version of RAP, replacing batteries ,replacing acoustic beacon , replacing backup VDR, replacing fuses and replacing consumable parts.2-trouble shooting : general trouble shooting , error codes and testing display of remote alarm panel . 3-location of spares and parts list 4-interface, data sentences and interface circuits.

8. CONCLUSION

In this original work the ability to read the data stored from all mentioned sensor is demonstrated using human-machine interface, including both the data video and audio, and representing the real time data for all kinds of navigation information. These data are up to certain extent very helpful for new accident investigation to acquire VDR that satisfies the three criteria: DATA RECORDER for navigation data and navigation aids VIDEO RECORDER for bridge environment, and external views, in addition to, AUDIO RECORDER from bridge environment and radio transmissions. External cameras for both video and IR, available on the bridge would allow proper assessment of the situation and this also will be helpful to protect the ship from piracy.

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