INVESTIGATIONS INTO SHIPBORNE ALARM MANAGEMENT

Conduction and Results of Field Studies

Florian Motz
Research Institute for Communication, Information Processing and Ergonomics, FGAN, Wachtberg, Germany

Michael Baldauf
Department of Maritime Studies, Hochschule Wismar University of Technology, Business and Design

Keywords: Alarm management, Field Studies, Safety of Navigation, Human Factors, Human Machine Interface, Integrated Navigation Systems.

Abstract: Safe navigation, including collision and grounding avoidance, is the main task of the navigating officer in charge to ensure the safety of sea transport during a ship's voyage. Modern ship bridges are highly-automated man-machine systems. With the enlarged number of systems and sensors onboard, and the increase of automation a proliferation of alarm signals on the bridge is associated. Field studies were performed on board of ships to investigate the situation with respect to the occurrence of alarms and its handling by the bridge team. Within this paper the conduction of the investigations, the used methods, and selected results for two samples of field studies will be presented. An outlook for a future alarm management onboard is given. The investigations were partly performed under the framework of a national Research and Development project funded by the German Ministry of Transport, Building and Urban Affairs, and under the European MarNIS – project, funded by the European Commission, Department for Energy and Transport.

1 INTRODUCTION

Safe navigation, including collision and grounding avoidance, is the main task of the navigating officer in charge to ensure the safety of sea transport during a ship's voyage from the port of departure to the port of destination. Modern ship bridges are highly-automated man-machine systems. Safety and efficiency of the ship operations are dependent, as all other complex man-machine systems, on the communication between humans and machines during the accomplishment of tasks. Humans can fulfil their assigned monitoring, control, and decision tasks most effectively, if the information flow between them and machines is adapted to the human skills and abilities (e.g., Lützhöft, 2004).

In the last years a strong increase of modern information systems on the ship bridges could be observed. Simple displays and control systems were supplemented or replaced by complex computer-based information systems. Information of different sensors and systems are combined in integrated navigation systems (INS). In order to support the mariner effectively on board, a task- and situation-dependent presentation of the information is a compellingly need.

With the enlarged number of systems and sensors onboard, and the increase of automation a proliferation of alarm signals on the bridge is associated. Alarm signals coming from various systems and sensors lead sometimes to a confusing and difficult manageable situation for the mariner, which is distracting him from his task to safely navigate the vessel. Redundant and superfluous audible and visual alarm announcements are appearing on the bridge, without a central position for visualization and acknowledgement of alarms. To enable the operator to devote his full attention to the safe navigation of the ship and to immediately identify any abnormal situation requiring action to maintain the safe navigation of the ship an alarm management harmonizing the handling, distribution and presentation of alarms on the bridge is necessary (Brainbridge, 1983; Sheridan, 1998).

Motz F. and Baldauf M. (2007).
INVESTIGATIONS INTO SHIPBORNE ALARM MANAGEMENT - Conduction and Results of Field Studies.
In *Proceedings of the Ninth International Conference on Enterprise Information Systems - HCI*, pages 136-141
DOI: 10.5220/0002373801360141

The International Maritime Organization (IMO) IMO has recognised this situation and decided to revise the exiting standards for INS and to develop requirements for an alarm management system. A working group coordinated by Germany was established to progress this work.

For the purposes of a detailed analysis of the current situation of the management and presentation of alarms on ships, field studies were carried out onboard of seven vessels.

The investigations were partly performed under the framework of a national Research and Development project funded by the German Ministry of Transport Building and Urban Affairs, and under the European MarNIS-project, funded by the European Commission, Department for Energy and Transport (Willems & Glansdorp, 2006).

2 INVESTIGATIONS

A series of field studies were conducted with the following aims:

- determine the occurrence of alarms on the bridge;
- gain knowledge about the operational needs of mariners in regard to the presentation and the operational procedures related to alarms and INS;
- determine operational problems with the presentation and handling of alarms and the operation of INS.

As the management and presentation of alarms is influenced by the type of ship, the year of construction, the installed equipment and grade of integration, the sea area, the training and education of the crew, the safety standards of the shipping company (Baldauf & Motz, 2006), these factors were taken into account to obtain a profound database.

The investigations were carried out onboard of a container vessel, a chemical tanker, two passenger ships, two ferries and a training vessel.

Due to the wide range of results and the different influencing variables, within this paper two field studies are selected and described exemplarily to give a detailed overview of the situation.

2.1 Methods of Investigation

Two methods were applied to fulfil the defined objectives:

- Recording (manually) of the occurrence of (navigational) alarms on the bridge;
- Interviews with mariners by means of structured questionnaires.

2.1.1 Recording of Alarms

The data collected was the actual frequency of alarms on the ship's navigation bridge. Onboard newly built ships a Voyage Data Recorder has to be installed. According to IMO performance standards such systems have to continuously record only selected main mandatory alarms of the bridge equipment. These recordings were therefore insufficient for the investigations.

The data was recorded manually in an prepared electronic data file specially designed for the purpose. Records were kept on:

- time/date the alarm appears;
- kind of alarm;
- system/device the alarm was announced;
- the alarm settings and limits;
- the presentation (visual/acoustical);
- the handling/reaction by the bridge team;
- the navigational situation;
- additional remarks.

Special focus was laid on the assumed dependencies of frequencies from sea areas. For the purposes of the studies the navigational situations were defined by a group of experts as "open sea", "coastal" (e.g. traffic separation as defined by IMO, coastal waterways, possible to determine position via landmarks) and "confined waters" with four different special cases: "pilotage districts", "harbour", "berthing" and "anchorage".

In addition the following was documented with two tables: the installed equipment (manufacturer / type), if alarms are switched ON and OFF, how the alarms are presented visually and acoustically, the used alarm limits dependent on the navigational situation.

Basis for the investigations was the analysis of the technical documentations and manuals of the sensors and navigational systems installed on the vessels. Simple changes in the configuration and the settings of the alarm limits lead to an increase or decrease of the announced alarms. Furthermore, a very important factor for the amount of alarms is the grade of integration of the systems onboard.

2.1.2 Interviews and Questionnaires

Beside recordings also interviews by means of a structured questionnaire were carried out onboard to gather the views of navigational officers on the presentation of alarms on the bridge, operational problems regarding the presentation and handling of alarms, and the occurrence of alarms.

Additionally interviews by means of a structured questionnaire were carried out regarding a task and situation depend information presentation on INS.

2.2 Samples

First sample is a study, which was conducted on board of a large container vessel of Post-Panmax-class with a loading capacity of more than 7.500 TEUs. The installed equipment was integrated and combined in the navigational bridge on a high integration level, see Figure 1.

Figure 1: Bridge with high integration level.

The investigations were conducted on a voyage in the North Sea departing from the Port of Hamburg and arriving at the Port of Southampton. The total voyage time was 29 hours. During the voyage good weather conditions were experienced with low winds and calm sea and only a few rain showers were encountered during the night.

The second sample is a field study carried out on board of a medium size passenger cruise vessel with a total capacity for approximately 1.500 persons (passenger 1.186 and 370 crew). The navigational equipment was integrated on the bridge on a high level as well.

The study was conducted on a voyage in the Western Mediterranean Sea departing from Palma de Mallorca, sailing via La Goulette, Tunis to the Port of La Valetta, Malta. The weather conditions were good with low winds and calm sea. The total observation time was 26 hours.

3 SELECTED RESULTS

3.1 Dependencies on Sea Area

3.1.1 Container Vessel

Under the mentioned conditions and used thresholds a total number of 205 alarms were counted on the container vessel. This means on average 7,6 alarms per hour. As this average is not very characteristic a more detailed analysis was carried out, investigating the distribution of alarms over the time.

The distribution of alarms on hourly basis for the entire voyage shows that for the first part of the voyage (from Hamburg port up to approximately the entry of the English channel) the number of bridge alarms was at a more lower average level per hour, the number rises up significantly during the second half of the observation period, when the English channel was passed through, with peak values between 20 and maximum 26 alarms per hour and finally again when the channel area was left and the port of Southampton was entered, with peak values of 22 and 23 alarms per hour.

The timely distribution reflects the dependence of the numbers of alarms from the sea area. This hypothesis is further confirmed when analyzing the registered alarms in relation to the navigational situation.

Figure 2 shows the average frequency of alarms per hour for the navigational situations. It illustrates that for the navigational situation "coastal" the frequency of alarms was approximately 4 times higher than the frequency of the alarm appearance in "open sea". The lower amount of alarms for "confined waters" in relation to "coastal" is related to the fact that alarms, e.g., collision avoidance were switched off via setting alarm thresholds for the closest point of approach (CPA) or the time to CPA (TCPA) to zero when leaving Hamburg harbor and under pilotage on the Elbe river.

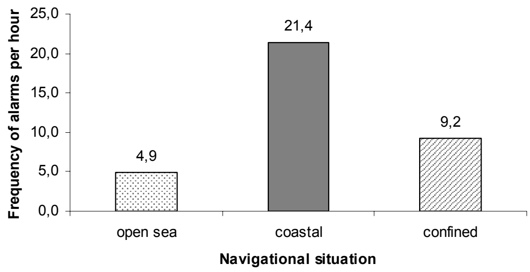

Figure 2: Average frequency of alarms for sea areas.

3.1.2 Passenger Vessel

During the observation period of 26 hours a total number of 220 alarms were counted. This means an average of 8,5 alarms per hour. As stated before this average is not very characteristic and a more detailed analysis was carried out, focussing more on the distribution of alarms over the time. Especially, it has to be mentioned, that the average value is to high as for certain times of open sea conditions data was not collected.

The distribution of appeared alarms on hourly basis reflects as for the container ship the dependency of the different sea areas. There are several peak values during the whole voyage. The maximum value of 40 alarms was observed during departure operations, when the ship left its first port. Other observed peak values of 17, 25 and 28 are also related to confined conditions with departure or arrival.

This is more clearly reflected when analyzing the registered alarms in relation to navigational situations. As the observation time varies in the various navigational situations, the average frequency of alarms per hour for the navigational situations is calculated (Figure 3). This shows that for the navigational situation "coastal" the frequency of alarms was approximately 3 times higher than the frequency of the alarm appearance in "open sea". The high amount of alarms for "confined waters" is related to the fact, that collision avoidance alarms were not switched off going in and out of ports, which lead to a high frequency of Automatic Identification System (AIS) target alarms. This clearly indicates a lack of the alarming algorithms presently applied to installed collision avoidance systems.

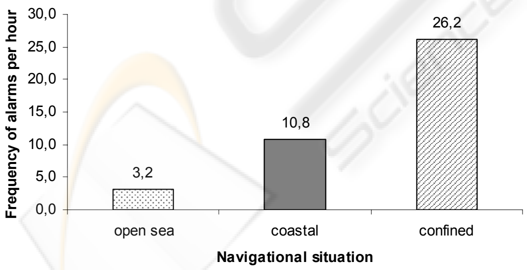

Figure 3: Average frequency of alarms for sea areas.

3.2 Dependencies on Equipment

3.2.1 Container Vessel

The system dependent distribution of alarms is shown in Figure 4. Most of the alarms are triggered by the radar device followed by the Global Navigation Satellite System (GNSS) and the gyro compass monitoring system.

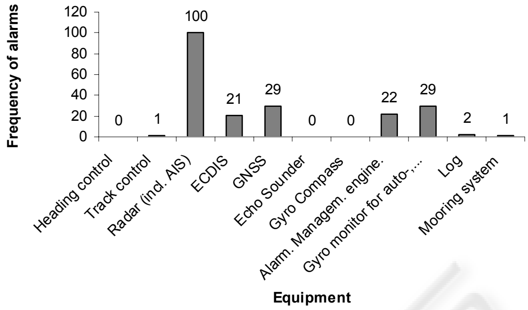

Figure 4: Frequency of alarms per device.

It has to be commented, that nearly all alarms occurring at the gyro monitor were caused by the loss of the differential signal at the GNSS device. Furthermore, in most cases after only a few seconds the differential signal was available again and the GNSS began to work in differential mode. This change was additionally announced by the system acoustically. However, in every case of loosing respectively receiving again the differential signal the officer of the watch (OOW) has to react on the alarm and has to acknowledge at least the gyro monitoring system. If not acknowledged immediately a further alarm was presented at other connected navigation systems as ECDIS (Electronic Chart Display and Information System) or track control.

As the majority of alarms were caused by the radar device, the specific technical configuration has to be considered. In the installation of the vessel the human machine interface (HMI) of the radar device serves also as integrated interface for in- and output of AIS data and the track control system.

A detailed analysis for the radar device shows that the majority of alarms are collision warnings triggered by AIS. This is an expected result when taking into account that for AIS the same limit values were applied as for tracked radar targets and the option for CPA/TCPA calculation was by default switched on to sleeping AIS targets. This in consequence leads to an overload of collision warnings especially in harbour approaches, where many AIS targets appear.

3.2.2 Passenger Vessel

The device dependent distribution of the alarms is shown in Figure 5. Most of the alarms are again presented at the HMI of radar device followed by the bridge alarm system, gyro compasses and ECDIS.

The gyro compass alarms are triggered by the gyro monitoring system, which informs about deviation between course information of first and second gyro compass. The same alarm appears on the bridge alarm system. At both systems the alarm has to be acknowledged independently. The relative great amount of ECDIS alarms are caused by deviations of the actual course compared to the planned course, deviations of the position compared to the planned route and when a route's waypoint was approached. The alarms were presented on the radar device too.

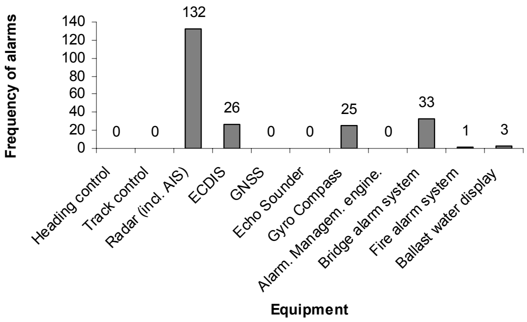

Figure 5: Frequency of alarms per device.

As for the container vessel the majority of alarms was presented at the human machine interface of the radar. Radar was also used as HMI for the handling of the AIS information as well as HMI for the track control system. Again, the majority of alarms are collision warnings and lost target alarms triggered by AIS. This is an expected result due to the fact that similar configurations were found and similar automatic alarm functions were applied as for the container vessel. However, the amount of lost target alarms was already significantly reduced by the OOW by deleting all targets, otherwise the number of such alarms would have been much higher.

4 DISCUSSION OF RESULTS

The results of the field studies and interviews confirm most hypothesis. Whereas the average number of alarms recorded is rather low, the peak values observed during the studies are more considerably. Situations with twenty and more alarms leave room for improvement of the relevant systems. The frequency of alarms depends very much on the navigational situation.

A further analysis of the results show, that difficulties in the handling and presentation of alarms are related, e.g., to the presentation of alarms and the necessary acknowledgement on various panels on the bridge, to the lack of a consistent alarm acknowledgment concept, to alarm propagation by a single incident, to the lack of indication of any priority of the alarms, to difficulties in differentiating the audible alarm signals and to the fact that in certain navigational situations too many alarms appear.

Furthermore, interviews with the officers show preferences:

- for a centralized alarm management display;
- for an indication of alarms according their priority;
- that the audible alarm signal for certain functional alarms, e.g., for collision avoidance, should guide the bridge team directly to the most concerned navigational workstation presenting the cause of the announcement and related information for decision support.

It can be concluded, that key issues to a significant improvement of the handling of alarms and in consequence to an enhanced integrated alarm management on board are, e.g.:

- the increase of the reliability of sensor data;
- improvement of alarming algorithms, e.g., by methods to combine data respectively information of different sensors;
- further development of the human machine interfaces to more transparent presentation of alarms;
- integration and connection of all navigational sensors and systems which will allow to design a consistent alarm management;
- task orientated integration and presentation of information on the displays.

5 SUMMARY AND OUTLOOK

Aimed at the improvement of shipborne alarm management of INS a series of empirical studies were performed to analyse the present state. For this purpose real alarm situations on board of vessels were continuously recorded. Interviews and questionnaires with experts were used additionally to collect data about the operational needs of the navigators.

With respect to kind and frequency of alarms a great variety was detected. According to the discussion of the results the strongest correlation is indicated in respect to the area related navigational situations. As one of the main reasons it was found, that the implemented alarm algorithms are fixed, e.g., for collision warnings, without suitable system options to adapt the alarming to the changing conditions of the different navigational situations.

A future alarm management should harmonize the operation, handling, distribution and presentation of alerts. To avoid the uncontrolled increase of alarms, a set of priorities based on urgency of the required response is needed to improve the operator's situation awareness and his ability to take effective action. Therefore a new philosophy is suggested for the prioritization and categorization of alarms. Alert is defined as umbrella term for the indication of any abnormal situation with three different priorities of alerts (IMO, 2006):

- alarm (highest priority) - immediate awareness and action required;
- warning - awareness of changed condition;
- caution - awareness of condition which does not warrant an alarm or warning condition, but still requires attention out of the ordinary consideration of the situation or of given information.

The three priorities should be indicated visual and acoustically in different ways.

To categorize the alerts further, the following two alert categories are specified.

- navigational alerts - functional indication of dangerous situation, e.g., collision warning, depth warning;
- technical alerts - equipment failure or loss.

Basic concepts for improvement of collision warnings are already available (Baldauf, 2004). Further research and development is needed and should be dedicated to apply the concept according to the functional approach for a new alarm management.

Finally, a central alert management HMI should be integrated to support the bridge team in the immediate identification of any abnormal situation, including the source and reason for the abnormal situation and in its decisions for the necessary actions. The central alert management HMI should be provided at least at the position from where the vessel is navigated and fulfil two major functions: indicating and identifying alerts, allowing the acknowledgment of alerts by the bridge team.

Primarily, all technical alerts should be integrated into the alert management, whereas the navigational (functional) alerts should be primarily presented at the most concerned navigational workstation presenting the cause of the alert and related information for decision support.

The central alert management HMI should then substitute the alarm announcement (functions) of the individual equipment to avoid the announcement of the same alert at two different systems.

ACKNOWLEDGEMENTS

The investigations were part of a project funded by the German Ministry of Transport, Building, and Urban Affairs. The authors would like to thank HAPAG-Lloyd and AIDA Cruises Ltd for their grateful assistance and all mariners who provided their knowledge in interviews on board.

REFERENCES

Brainbridge, L., 1983. *Ironies of Automation*. in: *Automatica*, 19, p 775-779.

Baldauf, M., Motz, F., 2006. *Operational Aspects of future Alert Management to support ship navigation. (in German)* In: Morten Grandt (ed.): *Cognitive Systems Engineering in der Fahrzeug- und Prozessführung.* DGLR-Bericht 2006-02, Bonn, ISBN 3-932182-51-0.

Baldauf, M., 2004. *Enhanced Warning Functions for on board Collision Avoidance using AIS and VDR information*, In: R. Dauer, A. de la Pena, J. Puig (editors): *International Congress on Maritime Technological Innovations and Research - Proceedings.* SCI UPC, Barcelona, ISBN 84-7653-861-8.

IMO, 2006. *Report of the IMO correspondence group on INS/IBS.* NAV 52/4. London: International Maritime Organization.

Lepsoe, A., Eide, M., 2005. *Field Study on Bridge Alarms*. Interim Sub-Task Report MarNIS WP2.4, Det Norske Veritas Oslo.

Lützhöft, M., 2004. *Maritime Technology and Human Integration on the Ship's bridge.* Dissertation No. 907, Linköpping Studies in Science and Technology. Sweden, ISBN 91-85295-78-7.

Sheridan, T.B., 1998. *Rumination on Automation*. in: S. Hishida; K. Inoue (ed.): Analysis, Design and Evaluation of Man-Machine-Systems. Reprints of the 7th IFAC/IFIP/IFORS/IEA Symposium, Kyoto.

Willems, C., Glansdorp, C.C., 2006. *MARNIS- Maritime Navigation and Information Services*. in: International Symposium Information on Ships, DGON, Hamburg.