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Innovation of Maritime Safety and Emergency Systems

Adaptation of solutions from aviation

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Degree Thesis

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DEGREE THESIS

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Abstract

This study concerns the improvement of safety and emergency systems on board vessels, by adapting existing solutions already used in aviation.

By combining research concerning solutions and user interface used for the detection and solving of non-normal occurrences, emergencies, and faults relating to navigation while underway in both aviation and at sea, I noticed that standards, regulations, and solutions in general are by far more advanced, standardized and strictly regulated in aviation then in the maritime sector.

The main objective of my study was to determine the feasibility of adapting some of the relevant systems developed for and used in aviation to the maritime sector, and to prove that they would be beneficial, improving safety, reaction time and problem solving in challenging situations and emergencies.

My secondary objective was to find concrete ways of adapting some of these systems, creating a prototype and testing the effects of its implementation in order to provide data from a non-abstract example in the real world.

My study involved extensive research in both fields, interviews with professionals, the creation of prototype solutions adapted to the maritime sector and their testing in a simulator along with a control group, and analysis of data, standards and regulations in order to arrive to my conclusion.

It is my hope that the result of this study could bring positive changes concerning safety and emergency systems aboard vessels in the future.

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Special Terminology and Abbreviations

APU: Auxiliary Power unit (emergency) generator for aircraft, usually generates electricity, high pressure air, and hydraulic power

ARPA: (in Maritime) Automatic Radar Plotting Aid

CPA: Closest Point of Approach (between two vehicles)

EBL: Electronic Bearing Line, a virtual line which can be placed on the radar screen to determine a bearing (degrees).

FAA: Federal Aviation Administration

GNSS: Global Navigation Satellite System (Such as GPS)

Gyrocompass: Navigational instrument which uses a high speed gyroscope as a reference to determine (true) north

Head-Up: When the heading of the ship (or aircraft) is fixed vertically up on the radar display instead of North being fixed

OS: Operating System, in this case referring to cockpit, bridge and ECR systems

QRH: Quick Reference Handbook (Booklet containing bullet points to be used in case of emergencies and non-normal occurrences on Aircraft)

SMS: Safety Management System (Consolidated documents relating to safety and procedures on board ships)

Stall: (In Aircraft) When the wing(s) no longer produce sufficient lift to keep the aircraft flying, due to the decrease or absence of airflow over the wing

Transponder: (Both Maritime and Aviation) A system that broadcasts data concerning the vehicle`s position, speed, heading, and possibly other pertinent details (like AIS in ships)

VRM: Variable Range Marker, virtual mark (usually a ring) which can be placed on the radar screen in order to determine range (distance)

VTS: Vessel Traffic Service, similar to air traffic control for aircraft however usually working in advisory capacity

1 Introduction

This Study concerns the improvement and innovation of Safety and Emergency Solutions used in the Maritime sector on board vessels, in particular on the bridge by adapting solutions from Aviation.

There have been previous publications considering the adaptation of solutions relating to safety from aviation to the maritime sector. The most relevant to this study is from the University of Strathclyde titled "*Can we learn from aviation: safety enhancements in transport by achieving human oriented shipping environment*" which, although is based on a similar idea, focuses mainly on the human factor and does not consider the solutions studied in this Thesis.

Many of the standards used in commercial aviation today were borrowed and developed from the far older Maritime Sector, this is partially due to the popularity of "Flying Boats" (Large commercial hydroplanes) which were the main mode of long-distance air transport in the first half of the 20th century. Procedures and terminology ("Captain, Cockpit, Airport, Stewardess"…) were borrowed from the Maritime sector and implemented in Aviation.

Due to its speed and efficiency of especially passenger transport over long distances, Aviation developed at a great pace during the second half of the 20th century, and the advancements of its automation, safety and human interface related systems has surpassed that of the Maritime Sector in general.

Due to their speed and agility, aircraft necessitate fast and accurate response in case of abnormal occurrences, failures, and emergencies while underway. The solutions designed to facilitate such response have been in constant development and are nowadays by far more developed than standard solutions used on board vessels.

Perhaps it is now time for the Maritime Sector to borrow some well-established, tested and working solutions from Aviation, and implement them aboard vessels.

1.1 Is it necessary to improve safety and emergency systems?

The Maritime Sector is constantly evolving with innovations in both the technology, the procedures, and the rules and regulations governing them, this is especially true for systems and solutions related to Safety. Despite all the improvement, accidents do happen. According to Allianz in 2021 alone there were 2703 incidents reported and 49 ships lost.

Although the yearly reported incidents and losses have a downward trend, the numbers are still relatively high. They cannot include the unreported incidents and accidents which are believed to be numerous, especially in underdeveloped and poorly regulated regions.

In my opinion it would be in the best interest of the maritime community worldwide if we considered all solutions which could positively contribute to safety in the maritime sector, and subsequently would reduce the number of incidents, accidents and fatalities.

1.2 Background of study

My personal fascination and interest in both aviation and the maritime sector led me to notice discrepancies between the level of development in safety and emergency related solutions, user interface, protocol, and systems in the two sectors. My idea was to test the feasibility of adapting some of the solutions from aviation to the maritime sector and to study the effects they would have.

After conducting research, creating and testing prototypes, I have selected four solutions the adaptation of which I studied more in depth.

1.3 Issues considered

When faced with an unexpected issue or abnormal occurrence on board while underway, we are often caught off guard. Typically, the following events occur: an audible alarm sounds from one of the many panels usually making a sound that is hardly distinguishable from other alarms, in more modern systems a consolidated alarm panel will tell us the name or at least the id. number of the alarm and the system it comes from, in older systems not even that. We spend time trying to figure out the nature and cause of the alarm while diverting some of our attention from actually navigating the vessel. Once we find what

caused the problems we either search for the procedure to solve it, ask for help, postpone the issue, or rely on memory items to try and solve the issue on our own. All of the above require time and attention which we might be able to afford at open sea or in port, but not in difficult traffic, weather, or navigational situations.

In aviation, things move more quickly, and it is rarer that a pilot can afford the time and attention required to identify an issue and solve it without initially knowing what it is, what procedures are required to solve it, and what caused it. The aviation industry has thus been forced to develop more efficient solutions for identifying and dealing with problems relating to safety and emergency systems.

In summary, the current standard systems designed to assist maritime Officers in identifying and solving issues on board while underway are not optimal and lack sophistication.

I believe that it is possible to adapt some of the aforementioned systems to the maritime sector making it safer and more efficient when it comes to dealing with emergencies, faults and system failures, and reducing the subsequent safety risks.

1.4 Aim of Study

The theory of implementing solutions from aviation to the maritime sector has been studied before. This study however concerns four main solutions which I believe could be implemented with relative ease and little to no regulatory modification but would bring considerable advantages relating to safety and emergency procedures on board vessels.

This study also covers the creation and testing of a prototype system involving the above-mentioned solutions in simulators.

As far as I am aware, the implementation of these specific solutions has not been studied before, thus the aim of this study is to conclude the feasibility and the advantages of implementing safety and emergency related systems from aviation to the maritime sector, in particular the four specific solutions studied. Hopefully, in the long term this will lead to improvement of safety and emergency related solutions and procedures in the maritime sector.

2 Methods

I have used literature research, quantitative research, interviews with experts, and prototype testing in order to determine the viability of my ideas, as well as the necessity and the feasibility of their adaptation in the maritime sector.

2.1 Literature Research

I have implemented literature research in my field of study. I have studied all prior publications I could find concerning the implementation of Aeronautical solutions in the maritime sector, to come up with new ideas. I thoroughly studied (standard) safety and emergency systems used on board commercial aircraft to find those that could improve Safety and bring benefits to the maritime sector if implemented.

2.2 Quantitative research

I have created a short questionnaire intended for seafarers working on the Bridge or in the ECR to complete, in order to determine a general opinion concerning the implementation of my ideas on board vessels. The questionnaire can be found on page 33.

2.3 Interviews with field experts

I have made more detailed interviews with a select group of people whom I thought would have great insight into the concerned systems and their use, following a detailed presentation of my ideas. I also made a detailed transcript and polls from their answers. The Interview template can be found on page 32.

2.4 Creation and testing of a prototype

- After having selected the solutions to be studied, I have decided to create a prototype system which enables the use of Standardized alarms, Aural warnings, and QRH both in digital and paper format in simulators.

- Resolution Advisory was not added to the prototype due to the modifications it would require to the Radar systems, I would instead rely on other methods to determine its viability.

  Note: Detailed description of all above mentioned solutions in Chapter 3

- I have created a scenario on the Transas Navi Trainer 5000 Maritime simulator, in which a cargo vessel is underway towards Helsinki in restricted visibility (fog) through the Archipelago. During the exercise I made the main Gyro compass fail.

- I ran the exercise on two separate bridges, one of which had a simple beeping sound signal indicating a problem, and no additional system installed. In the other bridge I added an aural warning to the standard beeping alarm, which announced “Gyro-Compass Fault” when the failure occurred.

In addition, I installed a new panel (in the form of a tablet computer) which contained detailed QRH checklists, such as “Gyro Compass Failure Alarm” as shown on page 30-31.

I invited officers and experienced management level students for the exercise without any prior briefing, and requested that they make a Route plan, and head towards Helsinki Main Harbour making logbook entries, and reporting on the radio, as in real life.

In each run I had a team (1-2 people) on the unmodified bridge as a control group, another team on the “modified” bridge containing my prototype.

The participants on the modified bridge were instructed on the use of the virtual QRH through the tablet but were not familiarized with any of the checklists within before the exercise.

I made the gyro compass fail when the ship reached a certain predetermined latitude, near to a group of islands where a fairway provides the only safe passage, in order to eliminate variables due to speed and course difference between exercises.

Once the gyro compass failed, I took note of the reactions and reaction times of both teams and monitored the movements of the vessel and the resulting situation.

3 Solutions

Following is a description of the solutions that I have chosen to include in the study as well as some that have been considered in previous studies for implementation in the maritime sector.

3.1 Solutions included in this study

After due consideration I have selected the following solutions based on the benefits they could bring to the maritime sector, the ease of their implementation to existing systems on board, based on opinions of field experts, and my own experiences and intuitions.

3.1.1 Standardized alarms for specific situations

In aviation alarms are categorized based on their severity, and subdivided into warning alerts, time-critical alerts, master caution, master warning, advisory… categories, all with their specific alerts. In addition, the most important and time critical alerts get their own specific visual, auditory or even haptic alarm which does not coincide with any other alert and is thus clearly identifiable and distinguishable.

Naturally, the generally less significant alerts do not get their own warning signals as to avoid confusion caused by the overwhelming quantity of alerts in the cockpit, and also to make the most important ones stand out.

The following is a list from the *Aircraft Owners and Pilots Association* webpage (aopa.org) which describes some of the most common cockpit warnings:

"**Engine or APU fire:** FARs require that engine and APU fires be indicated by a bell accompanied by red fire warning lights. No other cockpit warning uses the bell sound.

Stall: Approach to stall is indicated by a stick shaker, which physically vibrates both control columns, creating a rattling or shaking sound when aircraft speed is a minimum of 7 percent above the actual stall speed. Some stall warning systems also generate synthetic voice warnings ("Stall!") to indicate an approaching stall.

Overspeed: An overspeed "clacker" sounds when a limiting mach or airspeed is exceeded. Some aircraft also combine clackers with synthetic voice warnings that further clarify what speed is being exceeded (e.g., "Slat overspeed! Flap overspeed!").

Autopilot disconnect: Various kinds of siren, klaxon, or chime sounds, accompanied by red warning lights, signal that the autopilot has disconnected. On some aircraft, warning lights illuminate, but there are no aural warning sounds.

Stabilizer trim movement: On some aircraft continuous beeping or clicking sounds indicate that stabilizer trim is operating. Others, such as the Boeing 757, have no aural indication of trim movement.

Landing gear: A horn sounds and appropriate gear position indicator lights illuminate when an unsafe gear configuration exists. Once landing flaps have been selected, the horn normally cannot be silenced until the landing gear is properly extended.

Altitude alerter: A single chime or other distinctive tone, accompanied by a light, alerts pilots when they are leaving the current altitude or approaching a new one. Some alerter designs omit the tone, utilizing only the light itself.

Configuration warning: An intermittent horn or beeping tone warns when flaps, slats, stabilizer trim, or speed brakes are improperly configured prior to takeoff.

Pressurization: A continuous horn, accompanied by a red warning light in some aircraft, warns of loss of normal cabin pressure.

TCAS: A variety of voice warnings and visual displays warn pilots of traffic conflicts.

GPWS: Various voice warnings and attention-getting "Whoop, Whoop!" sounds warn of potentially dangerous situations, such as descent towards terrain when not in the landing configuration. — *VC"*

There are also regulations in place for the specific characteristics of alarms and warnings which are described in detail for instance in the FAA Advisory Circular AC No: 25.1322-1 which can be found on the official FAA webpage (faa.gov)

In the maritime sector although IMO does have guidelines concerning alarms and warning systems, they are vague and generalized compared to those in aviation, and presumably due to the large diversity in ship types, does not go into detail concerning standardization.

IMO does provide recommendations for standardization of alarms based on SOLAS requirements, and the Code on Alarms and Indicators adopted in 1991, however they are highly generalized and outdated. Being only recommendations, they are not enforced either.

In my opinion however although vessels differ considerably in technical solutions, purpose, size and shape, it would not be difficult to make at least operating system, company, and/or fleetwide standardization of major alarms possible as a first step towards general standardization in the field.

All the modifications necessary to make this possible could be software based, and on a large scale would not require considerable resources.

3.1.2 Aural Warning System

This Solution is a subdivision of the previous one “Standardized alarms for Specific situations”, however I have separated it due to its intricacy and as far as I am aware complete absence in major systems used in the Maritime Field.

On board most commercial aircraft, some of the most important alerts such as Fire, Stall, excessive Bank angle, Overspeed, too low, terrain… are announced by a pre-recorded voice playing in the cockpit. This makes it possible to identify the issue without diverting any attention from actually flying the plane, especially in a critical situation.

In the maritime sector it would be very useful to implement such a system on the bridge and in the engine control room announcing the most important alarms, malfunctions, and alerts.

As an example, on most ships the failure of navigational systems such as GNSS, gyrocompass, radar etc. do not produce their own dedicated alarms, even though modern systems recognize their failure. As a result, it might take several minutes to identify the issue which could not be available in challenging circumstances.

There have been multiple accidents ultimately caused by not noticing such failure in time ex: Finnfellow grounding near Överö. Link to the accident investigation report found in Sources.

Implementing an aural warning that states the issue recognized by the system would solve this issue, help the crew, and potentially prevent accidents caused by un-noticing and/or delayed reaction to system failure and other major issues.

3.1.3 Resolution Advisory

In aviation resolution advisory systems are a safeguard used as a last resort in order to prevent collision between two aircraft

The system is used to recommend an action (change of course/altitude) or inaction to the pilots in order to maintain sufficient separation between aircraft. The system uses data from the transponder of each aircraft involved in the traffic situation to recommend the best avoiding action to each aircraft thus avoiding a collision.

In the maritime sector, modern radars are fitted with ARPA, communicate with AIS and are able to process trial manoeuvres and give CPA warnings, however they do not recommend any action to increase the CPA with other vessels

Resolution advisory could be adopted in the maritime sector in the form of a system that could upon request recommend a course of action to increase separation with other vessels when the Officer in charge is overwhelmed by a traffic situation.

Although of the ones studied this is the solution that would require the most system development in order to be implemented in the maritime sector, I think it would be beneficial especially in complex traffic situations at sea.

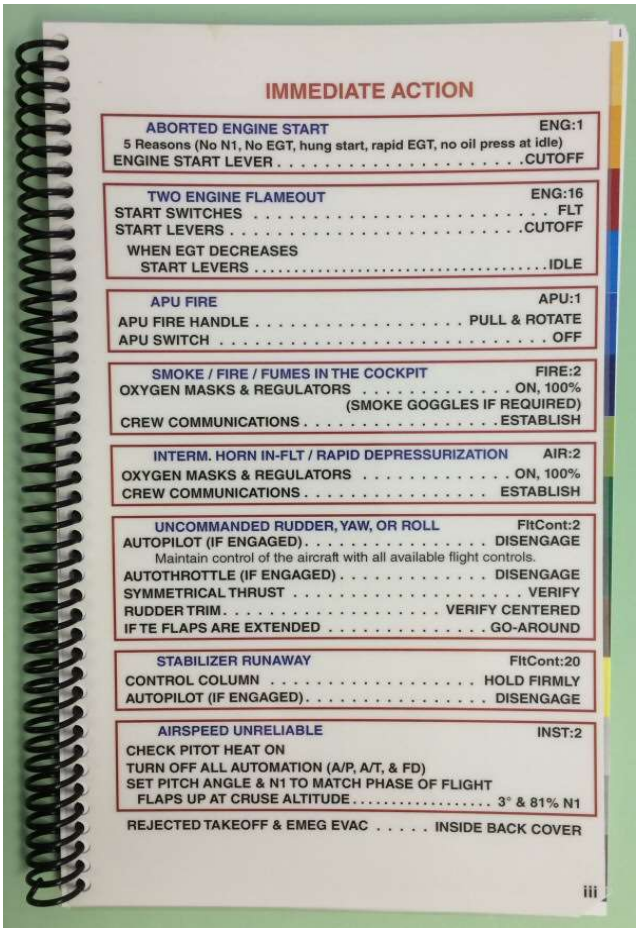
I also believe that with the advancements in autonomous vessel technology, the software required for such a system is not far from being developed, if it doesn't already exist, it would just need to be implemented on board conventionally crewed vessels as an advisory solution. In addition, resolution advisory could be further developed to give recommendations in situations other than traffic, such as system failures, based on the data it receives

3.1.4 Quick Reference Handbook (QRH)

Quick reference handbook onboard aircraft is a booklet containing simple instructions and checklists relating to emergencies, and non-normal occurrences on board. The booklet consisting of several subsections relating to different issues.

There is usually a separate section for immediate actions to be performed in case of major issues. It is to be used before consulting the more detailed manual or if there is no time to go into details at the time of the occurrence.

Extract from QRH, Immediate Action for a Boeing 737 Classic type aircraft:



IMMEDIATE ACTION

ABORTED ENGINE START — ENG:1
5 Reasons (No N1, No EGT, hung start, rapid EGT, no oil press at idle)
ENGINE START LEVER . . . . . .CUTOFF

TWO ENGINE FLAMEOUT — ENG:16
START SWITCHES . . . . . FLT
START LEVERS . . . . . .CUTOFF
WHEN EGT DECREASES
START LEVERS . . . . . .IDLE

APU FIRE — APU:1
APU FIRE HANDLE . . . . . PULL & ROTATE
APU SWITCH . . . . . OFF

SMOKE / FIRE / FUMES IN THE COCKPIT — FIRE:2
OXYGEN MASKS & REGULATORS . . . . . ON, 100%
(SMOKE GOGGLES IF REQUIRED)
CREW COMMUNICATIONS . . . . . .ESTABLISH

INTERM. HORN IN-FLT / RAPID DEPRESSURIZATION — AIR:2
OXYGEN MASKS & REGULATORS . . . . . ON, 100%
CREW COMMUNICATIONS . . . . . ESTABLISH

UNCOMMANDED RUDDER, YAW, OR ROLL — FltCont:2
AUTOPILOT (IF ENGAGED) . . . . . DISENGAGE
Maintain control of the aircraft with all available flight controls.
AUTOTHROTTLE (IF ENGAGED) . . . . . DISENGAGE
SYMMETRICAL THRUST . . . . . VERIFY
RUDDER TRIM . . . . . VERIFY CENTERED
IF TE FLAPS ARE EXTENDED . . . . . GO-AROUND

STABILIZER RUNAWAY — FltCont:20
CONTROL COLUMN . . . . . HOLD FIRMLY
AUTOPILOT (IF ENGAGED) . . . . . DISENGAGE

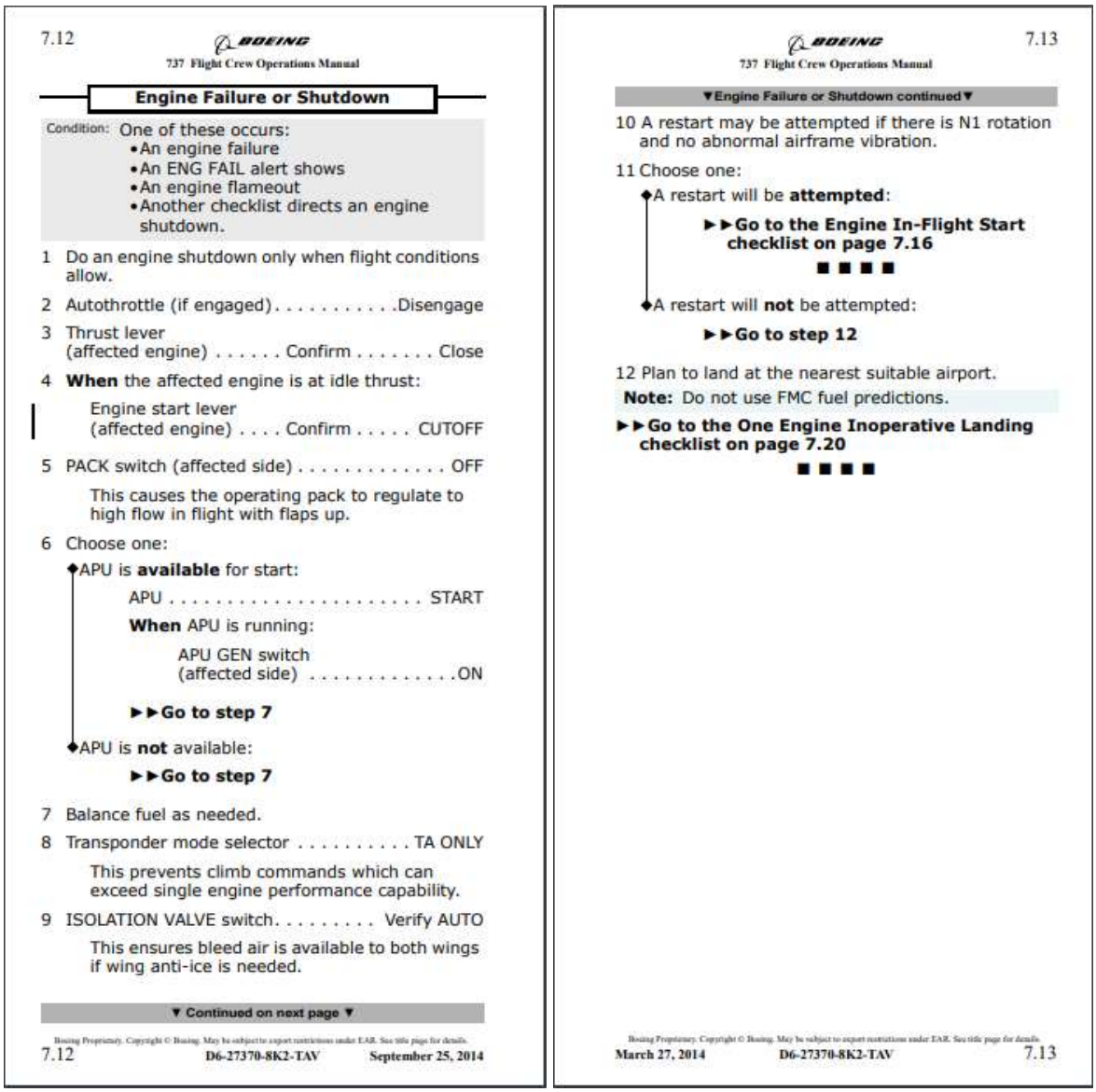
AIRSPEED UNRELIABLE — INST:2
CHECK PITOT HEAT ON
TURN OFF ALL AUTOMATION (A/P, A/T, & FD)
SET PITCH ANGLE & N1 TO MATCH PHASE OF FLIGHT
FLAPS UP AT CRUSE ALTITUDE . . . . . 3° & 81% N1

REJECTED TAKEOFF & EMEG EVAC . . . . . INSIDE BACK COVER

iii

The rest of the booklet contains step by step instructions on problem solving for non-normal occurrences and emergencies.

Following is an example from a Boeing 737 QRH relating to procedures in case of the in-flight loss of one of its engines:



7.12

BOEING
737 Flight Crew Operations Manual

Engine Failure or Shutdown

Condition: One of these occurs:
- An engine failure
- An ENG FAIL alert shows
- An engine flameout
- Another checklist directs an engine shutdown.

1 Do an engine shutdown only when flight conditions allow.

2 Autothrottle (if engaged) . . . . . .Disengage

3 Thrust lever
(affected engine) . . . . . Confirm . . . . . Close

4 **When** the affected engine is at idle thrust:

Engine start lever
(affected engine) . . . . Confirm . . . . . CUTOFF

5 PACK switch (affected side) . . . . . OFF

This causes the operating pack to regulate to high flow in flight with flaps up.

6 Choose one:

◆APU is **available** for start:

APU . . . . . START

When APU is running:

APU GEN switch
(affected side) . . . . . .ON

►►Go to step 7

◆APU is **not** available:

►►Go to step 7

7 Balance fuel as needed.

8 Transponder mode selector . . . . . TA ONLY

This prevents climb commands which can exceed single engine performance capability.

9 ISOLATION VALVE switch. . . . . Verify AUTO

This ensures bleed air is available to both wings if wing anti-ice is needed.

▼ Continued on next page ▼

7.13

BOEING
737 Flight Crew Operations Manual

▼Engine Failure or Shutdown continued▼

10 A restart may be attempted if there is N1 rotation and no abnormal airframe vibration.

11 Choose one:

◆A restart will be **attempted**:

►►Go to the Engine In-Flight Start checklist on page 7.16

■ ■ ■ ■

◆A restart will **not** be attempted:

►►Go to step 12

12 Plan to land at the nearest suitable airport.

Note: Do not use FMC fuel predictions.

►►Go to the One Engine Inoperative Landing checklist on page 7.20

■ ■ ■ ■

(Above content is the property of Boeing, do not copy or distribute)

In the maritime sector, the SMS regulated by the ISM Code has similar emergency procedures, however there are no guidelines for their format. Oftentimes on board ships they are kept in bulky binders on a shelf, where finding and using them in an emergency is difficult and inconvenient.

The ISM Code however is very vague concerning the actual implementation of SMS documents on board, and does not provide guidelines concerning format.

Some companies (ex. Viking Line) have already developed and are using checklists similar to QRH, which they keep accessible in the seat pockets on the Bridge.

In my opinion it would be beneficial to normalize such handbooks across the industry as they contain critical information on the right things to do in an emergency and the order to do them in.

In a high stress situation such as an emergency or non-normal occurance, it is common for people to act instinctively and to forget certain things, which on board a ship could lead to even larger issues. Having a QRH accessible on the bridge and possibly in the ECR as well would prevent, or at least highly decrease the possiblity of that happening.

Boeing 737 is one of the most produced and widely used commercial aircraft in the world, that is why I chose use its QRH as an example

3.2 Other Solutions to be considered

Following are some other solutions that I have not included in my study, but I think are worth consideration for implementation in the Maritime sector.

3.2.1 I.L.S.

Instrument landing system, used to guide planes in on their approach to a runway. Especially useful in bad visibility, the system uses vectored radio signals to form a virtual corridor for the incoming aircraft, which is interpreted by the systems on board. The position of the plane compared to the ideal approach is then relayed to the pilots

It would be helpful to install such a system especially in archipelagos, narrow fairways, and rivers, as an extra navigational aid to prevent grounding, deviation from course, and other such accidents

3.2.2 TCAS

The most common form of resolution advisory system, it communicates with its counterparts on other vessels, and when the risk of an imminent collision is detected, it gives a possible solution to all participants of the traffic situation. For example: it tells plane A to climb and plane B to descend.

It would take a lot of work to implement such a system in the maritime sector, but it would probably help prevent collisions.

It could also be installed on small vessels such as pleasure craft, which don't usually have any systems to aid collision avoidance, as the system doesn't require extensive hardware. In aviation even gliders and sport aircraft use it.

There is already a project by OFFIS considering its adaptation, details can be found on the following link: https://www.offis.de/offis/projekt/mtcas.html

3.2.3 ATIS

Automated Terminal Information System is a system used at airports which records and automatically broadcasts information related to weather, traffic, and Notices to Air Mariners for the area.

It would be useful to have such a system available on a VHF channel in busier areas in order to make sure that vessels are well informed even without a pilot on board, or VTS interaction.

3.2.4 Ram Air Turbine

R.A.T. is a small propeller fitted to a hydraulic pump and a small electric generator, which can be deployed in case of the loss of engines, hydraulic power, and/or electric power on board the aircraft. The small turbine provides power to basic navigational systems and, controls and hydraulically operated or assisted control surfaces.

In some cases the propeller or fan of the main engine (propulsion) is used instead of an auxiliary propeller to the same effect.

Such a system could be fitted to conventionally propelled vessels in order to provide power to the rudder and its controls in case of a blackout, maintaining at least some directional control while the vessel is still underway, and providing extra time to restore power. Groundings, allisions, and other accidents are often caused by a blackout.

3.3 Comments

The company NAPA has also developed a digital solution for decision support for fire and damage control. The program containins ship specific emergency checklists customizable by the companies. Although the use of their solution is different to what is considered in the study, it shows the possibility of implementing digital emergency support solutions on board, which could relate to both QRH and Resolution advisory. If companies such as NAPA would cooperate with navigation and engineering system manifacturers, at least digital QRH and resolution advisory could be very easily implemented, and could even be based on existing software.

4 Results

Note: Results of literature research are covered in the chapters above

4.1 Quantitative Research

The questionnaire was sent to seafarers from both deck and engineering department whose work at least partially takes place on the bridge or in the Engine Control Room. The questionnaire was intended to collect the opinions of seafarers with different levels of experience in both departments.

The participants were not told about details concerning this study, nor that the ideas come from, and are already used in aviation.

Following are the results from 45 participants

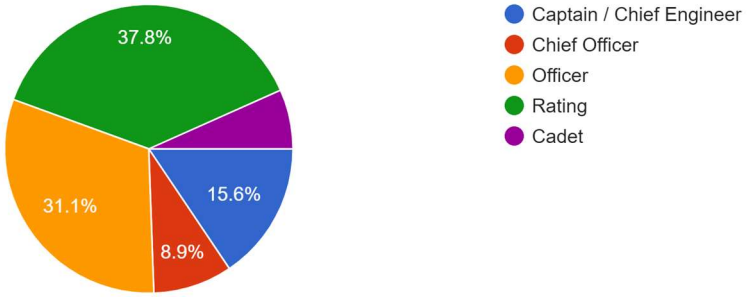


Figure 1. Ranks

I managed to obtain responses from a large variety of ranks and levels of experience.

4.1.1 Answers

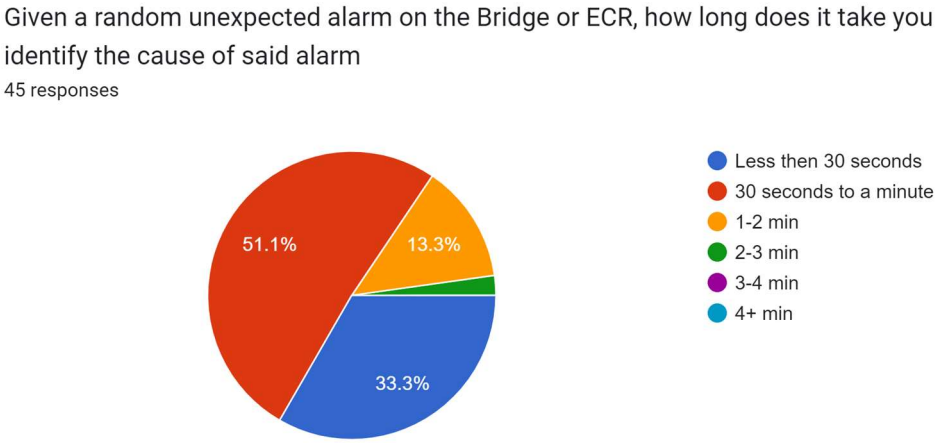


Figure 2. Alarm identification

As shown above, about 66% of participants take over 30 seconds to identify the cause of a random alarm, during this time attention is diverted from other tasks such as navigating the ship and maintaining watch in the ECR.

- When asked whether the time it takes to identify the cause of an alarm is adequate, sometimes takes too long, or takes too long, only 47% of the participants answered “Adequate”.

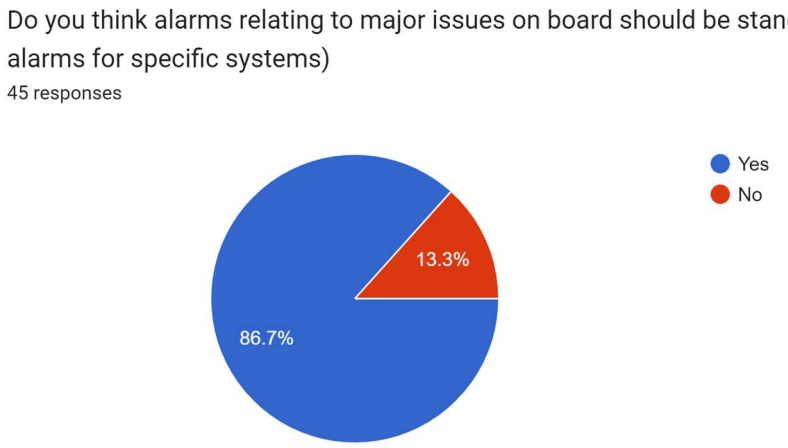


Figure 3. Standardized alarms

As shown above, a large majority of the participants support the idea that alarms relating to major issues should be standardized.

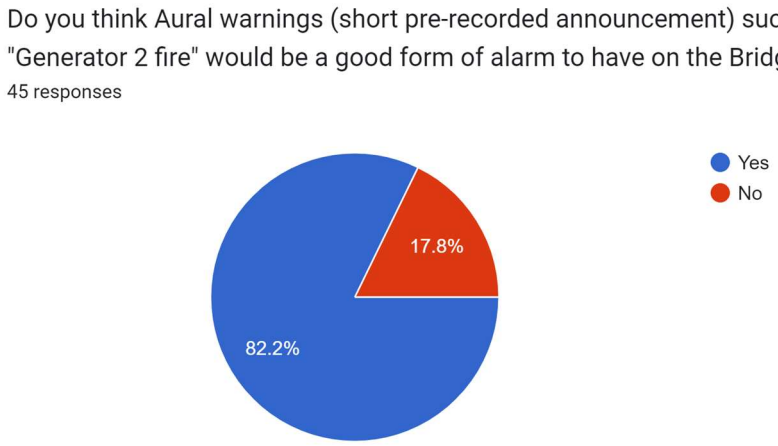


Figure 4. Aural warnings

Over three quarters of the participants think that Aural warnings would be a good form of alarm to have on board.

- QRH

“Do you think it is necessary to have a binder or computer containing basic checklists for emergency procedures ("mini SMS") available on the Bridge/ECR for reference in case of non-normal occurrences, emergencies?”

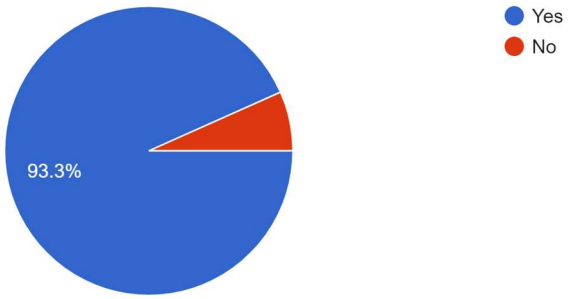


Figure 5. QRH

The question contained a very brief description of QRH. 42 of the 45 participants think it would be a good idea to implement such solution on board.

- **Comments**

Below are some of the most pertinent comments, however all of them can be found in on page 34.

"1 aspect to consider: When joining a new vessel it is not possible to familiarize with alarms before these accure. Meaning before incident or case really happens.."

" A physical binder is more efficient for checklists in an emergency, also laminated lists with a dry wipe pen is even better. Bonus point is that it cannot fail as electrical systems (computers) could."

"Hard to give answer because different alarms take different amount of time to find/solve. Also some alarms are less important than others so just alarms in general can take between 10sec to one day to figure out depending on the severity of it. On a normal day you can easily get 10-20 alarms and probably most of them are something that people onboard knows about already and they basically just gets resetted and all back to normal. That's why these questions can be hard to answer because the time frame to find out is very dependet on what kind of alarms and the severity."

"Most cruiseships have these very specific alarms in place aswell on the bridge not only in the ECR"…

4.2 Detailed interviews with field experts

I have questioned several Seafarers concerning the solutions proposed by this study, however in this section I am including the detailed interviews made with three individuals whom I thought would have great insight into the concerned systems and their use due to their expertise.

Below is a list of the individuals who took part in the detailed interview, as well as the reason I requested to interview them

- Emilia Lindroos – Lecturer – She teaches maritime students about systems used in navigation and their use both in theory and in the simulator, thus has great expertise concerning them.

- Johan Klawér – Captain, Line Pilot at Viking Line – He uses the said systems every day at work and navigates in challenging areas where reaction time is of essence in case of an issue (archipelagos). Also, due to his experience which led up to his position as a line pilot.

- Bo Lindroos – Simulator Manager – Managing simulators he is highly familiar with different types and brands of bridge systems, their design, working, and use.

I began each interview by giving a detailed presentation concerning the solutions, similar to paragraph 3.1. thus, the participants were already familiar with them when giving their answers and comments.

Note: In the following four paragraphs, text between quotation marks is a word for word transcript of the interviewee's answers, text between parenthesis was not said but is used to complete a sentence, plain text also describes the interviewee's answers but is a summary and not a word for word transcript.

4.2.1 Interview with Emilia Lindroos

- **(Highest) Position on board** – Chief Officer (currently university lecturer)
- **Experience** – 15 Years
- **Main ship and OS types** – Cargo / Furuno and Consilium

- **Getting a random alarm on the bridge relating to navigation or system failure**
  It takes a couple of seconds to identify alarms I am familiar with, but at least 2-3 times a week I encounter alarms I am not familiar with and have to consult a manual.
- **How long does it take to identify the issue –** It depends on the nature of the issue
- **Do you think that the time it takes to identify alarms is (adequate / too long)** – "Depends where you are" At open sea with limited traffic we can have enough time to consult manuals and to find the issue, but in challenging conditions we might not have time to spare at all, "then for sure it takes too long time" the alarm should be identified immediately.

- **Opinions concerning Standardized alarms for specific situations**
  "I think it's a great Idea" It is always a mess when different manufacturers have different system functions, naming systems. Although standardization would be a difficult task to achieve, staring with the alarms is a good idea. At least fleetwide and/or company-wide alarm standardization would be great, perhaps later we can think even larger. With people changing between vessels the lack of alarm standardization leads to confusion.
- **Opinions concerning aural warnings**
  "Interesting and useful" it is also used in some cars. For example in the case of a simulated gyro compass failure in school "it takes students many-many minutes to figure it out"
  "I would really like if the bridge system would tell me what`s wrong rather than me having to search for it by myself in a situation where you don`t have really time to search "

- **Opinions concerning resolution advisory**
  It would be useful, especially in the beginning of an Officer`s career but it is important not to rely on it solely for determining the best course of action. Overall, it would improve safety in real emergency situations, but it should mainly be used as a last resort rather than a constant reference.

- **Opinions concerning QRH**

  We already have it implemented according to ISM code in the form on SMS emergency procedures. It is however up to the vessels and company`s procedures whether they have pertinent and well made, thought through emergency procedures printed and accessible on the bridge.

  QRH is a great idea, it would increase safety a lot especially when faced with unexpected scenarios, it would be very useful

  It should be up to the owner to decide whether they prefer a virtual (computer) format or a handbook, but I would definitely recommend paper format

- **Other comments**

  "Very interesting, I hope that this is the future"

  Using examples from aviation would help and lead to improvement.

- **General opinion**

Characteristics **Solutions**	Overall Beneficial	Improve Reaction time	Improve safety	Help problem solving in an Emergency	Unnecessary
Standardized alarms for specific situations	Yes	In time after getting used to it	Yes	Yes	No
Quick reference handbook/software	Yes	Decrease the time it takes to do the right thing	Yes	Yes	No
Resolution Advisory	Yes, but only for emergencies	Decrease the time it takes to do the right thing	Yes	Yes	No
Oral Warnings	Yes	Yes	Yes, as long as it works correctly	Yes	No

4.2.2 Interview with Johan Klawér

- **(Highest) Position on board** – Line Pilot
- **Experience** – 12 Years (as Officer or higher)
- **Main Ship types / OS types** – Passenger RoRo / Furuno, Adveto, Wärtsilä NACOS
- **Getting a random alarm on the bridge relating to navigation or system failure, how long does it take to identify the issue** – with common alarms quite quickly, with unclear alarms you need to search around.
- **Do you think that the time it takes to identify alarms is (adequate, too long)** – Sometimes it takes too long, except with alarms that you often have

- **Opinions concerning standardized alarms for specific situations:**
  "I think it's good because (as it is) now you can have a beeping sound somewhere and you don't really know what it is. If we would have standardization, even when you hear the first alarm signal you would know already, ok it's that one...(For) the main components at least, if you have for everything then it's too much." If you get an alarm in a difficult navigational situation especially, it would help to know directly what it is. You can start the problem solving earlier

- **Opinions concerning aural warnings:**
  I think there is yes on every question (in the table below)
  "That would be a good thing. If something happens, and there is (for example) a lot of people on the bridge, and alarms sounding everywhere, you would give much more attention to it, so I think it's good"

- **Opinions concerning resolution advisory:**
  "Of course, it's always good, but I noticed that when I was a new officer, I used the trial maneuvers and everything quite a lot, then with more experience I used them less" Nowadays I use true trails and relative vectors more often.
  If its quick and easy to use its better, but for me it's easier to do it my way

- **Opinions concerning QRH:**

  "On Viking Line we have these checklists for blackout and engine failure, bomb threat, MOB … in A4 format, we have them on the bridge in the back of my chair so I can just take it. Little bit in that direction we are moving already" but this is just company procedure. They will help in every situation.
- "Concerning NAPA decision support program what I noticed is that you need to be quite familiar with it in order to get all the help you can get" If it is in a digital format it should be easy to use.
- **Other comments:**

  Also some BNWAS systems could use some improvement and possiblilty of specialisation

- **General Opinion:**

	Overall Beneficial	Improve Reaction time	Improve safety	Help problem solving in an Emergency	Unnecessary	
Standardized alarms for specific situations	Yes	Yes	Yes	Yes	No	
Quick reference handbook/software	Yes	Yes	Yes	Yes	No	
Resolution Advisory	Maybe *	Maybe *	Maybe *	Maybe *	See comment	
Oral Warnings	Yes	Yes	Yes	Yes	No	

* See comments above

4.2.3 Interview with Bo Lindroos

- **(Highest) Position on board** – Chief Officer (Currently simulator manager)
- **Experience** – 14 years at sea, 20 Years Simulator
- **Main Ship types OS types** – Mainly Cargo, Most familiar with Sperry, somewhat familiar with all types

- **Getting a random alarm on the bridge relating to navigation or system failure**
  It depends on the alarm, between 5 seconds and minutes
- **How long does it take to identify the issue –** It depends on the nature of the issue
- **Do you think that the time it takes to identify alarms is (adequate, too long)** – Sometimes it takes too long, it would be best to have the alarms centralized
- **Opinions concerning standardized alarms for specific situations:**
  "You hear often from seafarers that normally the least dangerous alarms are the noisiest on board the bridge" and the most dangerous alarms produce only a faint "beep"
  I think it would be a great idea, I have been in a situation where we had a catastrophic engine failure. Having gone to the bridge, there were a lot of alarms, fire, engine,… We went through them one by one. The hardest to identify turned out to be a NAVTEX distress message from a vessel hundreds of miles away. It would be great to have standardization for these alarms, so that it's not beeping everywhere anymore
- **Opinions concerning aural warnings:**
  That would be really beneficial. You would get directly an idea of what it is, when you get an alarm. You don't need to start to look for the cause of the problem.
- **Opinions concerning resolution advisory:**
  "Would be helpful especially for new guys but also for mor experienced (people)."
  I have heard of such system being developed for fire and flooding.
- **Opinions concerning QRH:**
  "Some companies have that, but it's based on company decisions" It would help you to do things in the correct order, and to do everything that is needed. For instance, in Pilot exemption tests that we do candidates very often forget to inform the VTS in case of an emergency. It would be especially beneficial to avoid forgetting such things.
- **Other Comments:**
  "As I said before, when you have these different alarms, sometimes the most important alarms have the least volume or (they are) not blinking. It would be a good thing to have some different alarms, standardized. Also moving to a different vessel, you would not have to find out what alarm is what."
  "You are on a good way"

- **General Opinion:**

	Overall Beneficial	Improve Reaction time	Improve safety	Help problem solving in an Emergency	Unnecessary
Standardized alarms for specific situations	Yes	Yes	Yes	Yes	N
Quick reference handbook/software	Yes	Improve time it takes to do things in the correct order	Yes	Yes	N
Resolution Advisory	Yes	Most of the time	Yes	Yes	N
Oral Warnings	Yes	Yes	Yes	Yes, it would make it quicker	N

4.3 Creation and testing of a prototype

I have tested several possibilities and different methods of implementation for the solutions in question, with the help of teachers and peers. After the tests I arrived to the conclusion that the most eloquent solutions (at least for this prototype) would be the following:

The QRH would be in digital format on a tablet computer. The tablet could rely on its battery if power was lost and is easily movable. All other apps would be blocked other than the QRH (in this case Adobe Acrobat) to ensure reliable and fast accessibility. The tablet also allowed for quick access to the adequate checklist and had the possibility of adding notes directly on the checklist if necessary.

The best solution I found for simulating standardized alarms for specific systems and aural warnings was to use a (receive only) radio on the bridge, connected to one in the control room. I have recorded several pre made alarms and aural warnings on an audio recorder, and played them as required on the above mentioned radio.

We made three runs with one modified and one unmodified bridge each, both in separate exercises but in the same scenario (meaning they started in the same position at the same time but couldn't see or interact with each other).

4.3.1 Control Groups

The control groups all had a good route plan and started out normally. One deviated from their intended route due to difficulties familiarizing with autopilot, however later rejoined the planned route.

I made their primary gyro compass fail minutes before a turn they all intended to make prior to entering a narrower channel near the Helsinki Archipelago. They were notified of the issue by a simple "beeping" alarm. Initially neither of them could figure out what caused the alarm, and all three attempted the following turn. Two of the three vessels ended up grounding, one of them alluding with rocks as well. The third vessel unintentionally exited the channel, and stopped the vessel before figuring out the issue, but could not solve it without assistance.

4.3.2 Groups using the prototype

During the first half of the exercise there were no differences worth mentioning with the control group. After the Gyro compass failure though, the differences were remarkable!

After receiving the alarm and the Aural warning (stating 2x"Gyro Compass Fail") all three groups successfully found the correct QRH checklist and followed it. Two of the three groups managed to switch to the operational secondary gyro before completing the turn. The third group followed the recommendation of the QRH to switch the radar to head-up, and completed the turn relying on magnetic compass, after completing the turn they also switched to "Gyro II" as per the checklist. Neither of the three groups even came close to exiting the safe channel and continued their journey to Helsinki uneventfully.

4.3.3 Result

The prototype solution had a 100% success rate in the simulated exercise. In this exercise the lack of the prototype resulted in dangerous situations and damage to the vessel.

5 Conclusions

Based on all the above I have concluded the feasibility and the advantages/disadvantages of implementing each solution considered to the maritime sector. All my conclusions are based on the results of this study.

5.1 Implementing Standardized alarms for specific situations

Most seafarers encounter difficulties when identifying uncommon alarms. The majority think that alarms should be centralized and standardized for specific situations. In emergency situations especially, it would be very beneficial not having to search for the source of a beeping noise, and consulting manuals to find the cause of an unusual alarm.

Standardization would not be an easy task to achieve, with different systems by different manufacturers each having their own approach towards them, but multiple manufacturers have taken steps towards centralizing alarms at least for their systems and those they are compatible with. It would be a good first step to start with fleetwide and/or companywide standardization of alarms, this would also facilitate crew transfer between vessels.

Standardization of alarms would improve safety by reducing the risk of misidentifying alarms, facilitate problem solving in an emergency, and reduce reaction time, but would necessitate detailed familiarization for all crew involved.

5.2 Aural Warnings

This solution got overwhelmingly positive feedback. Closely related to standardization of alarms, in addition to the benefits of standardization, this solution would ensure that major alarms are not missed and can be identified immediately and unmistakably. Especially emergencies where time is of essence it would really make a difference.

It is important however that only the most important alarms be connected to aural warnings, as an exceeding amount of aural warnings can be overwhelming, distracting. Aural warnings are supposed to attract attention and share important information at the same time, having too many of them would have the opposite effect by desensitizing crew members.

Implementation of this system would improve overall safety, reaction time, and would lead to faster problem solving in an emergency, however it has to be well designed in order to avoid unnecessary or false alarms.

5.3 Resolution Advisory

This is a slightly divisive solution however its implementation would overall still be useful. Each Officer has their own habits when it comes to maintaining traffic separation, and collision avoidance thus the system's use should be optional.

When encountering challenging traffic situations, experienced officers will often instinctively use a combination of vectors, trails, EBL, VRM and other basic ARPA tools to get a detailed picture of the situation at hand and make a plan accordingly. Less experienced officers however often take more time, checking trial manoeuvres and CPA-s to come up with a plan. In any case all could benefit from having the possibility of getting a recommended action to consider.

It is important however that the system be used only for advice in difficult traffic situations, and not relied upon solely for decision making. It is also important that the software be very well made, to avoid getting bad advice from it.

Overall, if well made, the system would be beneficial and would help problem solving in challenging situations, leading to improvement in safety.

5.4 Quick Reference Handbook

This is the solution that got the most positive feedback during the study. Almost all involved agree that QRH should be used on board, and in some companies, similar solutions already are.

The majority think that the analogue (paper/laminate binder) format is still superior due to its reliability, however it should be up to the companies, and crews to decide whether to have it in analogue, digital format, or both.

I haven't found any disadvantages of the implementation of QRH on board, and it would be perhaps the easiest solution to implement, as it requires minimal effort, and legal provisions already exist for it in the ISM code. The only thing that would be left to do is to standardize its possible formats, and its use aboard all commercial vessels.

Implementing QRH on board would be highly beneficial, improving safety on board by making sure the right actions are taken in the right order in an emergency, and helping in problem solving.

5.5 Overall Conclusion

The implementation of the studied solutions in the maritime sector is feasible and would result in safety improvements.

Collectively, the solutions would ensure that faults, failures, and emergency situations are noticed, recognised, and that all the right actions are taken in the right order in order to mitigate them.

All four solutions should be implemented to the maritime sector.

6 Resources

Allianz 2021 Report :
https://www.agcs.allianz.com/news-and-insights/news/safety-shipping-review-2021-press.html
Study is from the University of Stratchclyde titled "Can we learn from aviation: safety enhancements in transport by achieving human oriented shipping environment":
https://www.researchgate.net/publication/304529978_Can_We_Learn_from_Aviation_Safety_Enhancements_in_Transport_by_Achieving_Human_Orientated_Resilient_Shipping_Environment
Cockpit Warning Systems:
https://www.aopa.org/news-and-media/all-news/1997/april/pilot/cockpit-warning-systems
AC No: 25.1322-1
https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_25.1322-1.pdf
IMO Code on Alarms and Indicators
https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/AssemblyDocuments/A.686(17).pdf
Finnfellow Accident Report:
https://www.turvallisuustutkinta.fi/material/attachments/otkes/tutkintaselostukset/en/vesiliikenneonnettomuuksientutkinta/2000/b22000m_tutkintaselostus/b22000m_tutkintaselostus.pdf
Use of QRH in aviation
https://www.skybrary.aero/articles/quick-reference-handbook-qrh
Adaptation of TCAS to the Maritime sector
https://www.offis.de/offis/projekt/mtcas.html
NAPA Decision support emergency computer
https://www.napa.fi/software-and-services/ship-operations/napa-emergency-computer/
Google Forms (used to create questionnaire)
https://www.google.com/forms/

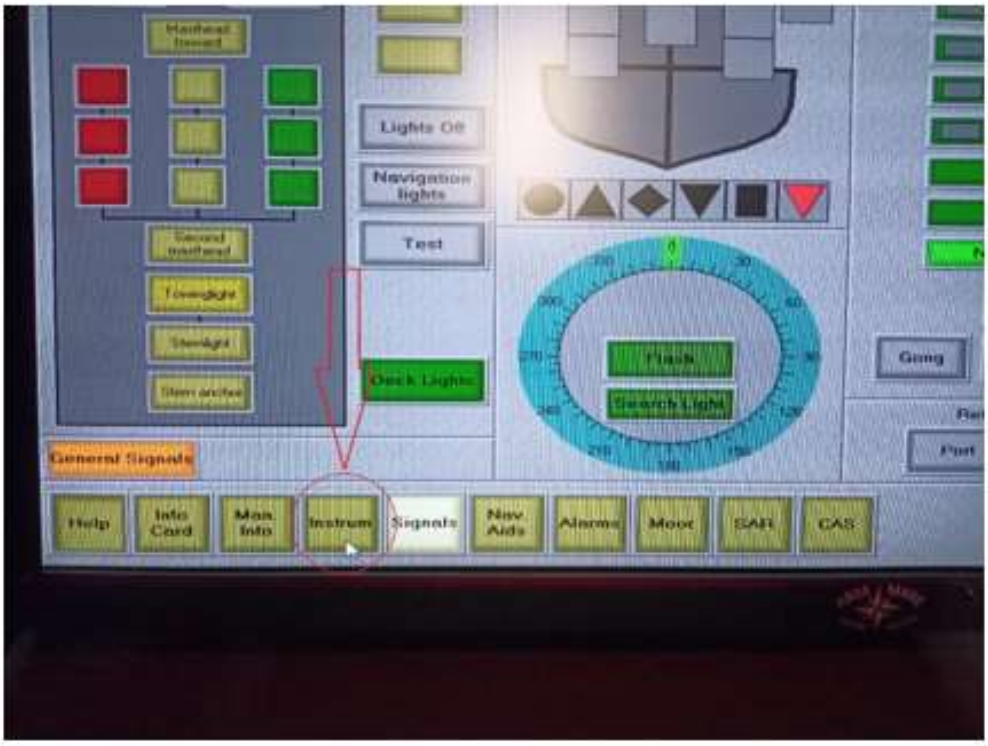
Appendix

1 QRH Gyro Compass Failure

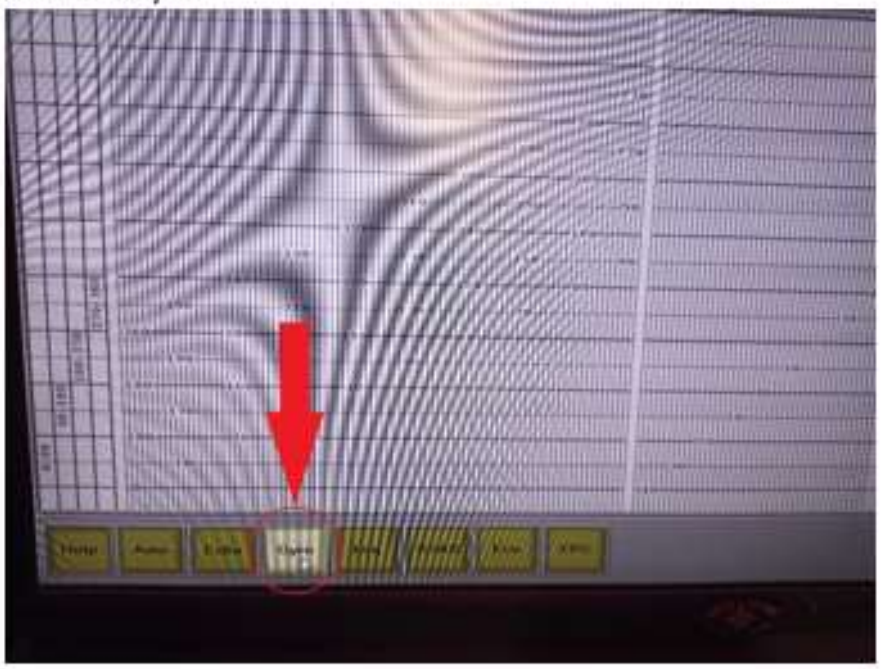
Gyro Compass Failure Alarm

Recommended actions

1. Switch to Manual Steering
2. Radar to Head. Up and adjust range
3. Navigate (Determine your situation, use mag.compass for heading reference keep in mind variation and deviation)
4. Ask for help if necessary
5. Adapt your speed
6. When safe to do so switch to the other Gyro Compass
   - On the Conning display Select “Instrum” Menu



- Select “Gyro”



- Switch to the other Gyro Compass (1to2 or 2to1)

- If it works, Continue as normal
- If it doesn’t work, continue using mag.compass for reference (keep in mind variation and deviation)

2 Interview

Innovation of Maritime Safety and Emergency Systems

Adaptation of existing solutions from Aviation

By Adam Zupko

Interview

- Name
- (Highest) Position on board -
- Experience –
- Ship types OS types –
- Getting a random alarm on the bridge relating to navigation or system failure
- How long does it take to identify the issue –
- Do you think that the time it takes to identify alarms is (adequate, too long) –

Notes:

- Aviation Standardized alarms for specific situations, similar sounds -
- Resolution Advisory
- Oral warning -
- QRH

- Implementation of following solutions in the maritime sector:

	Overall Beneficial	Improve Reaction time	Improve safety	Help problem solving in an Emergency	Unnecessary	Comments
Standardized alarms for specific situations						
Quick reference handbook/software						
Resolution Advisory						
Oral Warnings						

3 Questionnaire

Maritime alarm and safety systems

This is a census for a Maritime Management thesis, intended for Seafarers (Deck and Engineering)
By Adam Zupko

* Required

1. What is/was your highest rank on board *

Mark only one oval.

- ◯ Captain / Chief Engineer
- ◯ Chief Officer
- ◯ Officer
- ◯ Rating
- ◯ Cadet

2. Given a random unexpected alarm on the Bridge or ECR, how long does it take you on average to identify the cause of said alarm *

Mark only one oval.

- ◯ Less then 30 seconds
- ◯ 30 seconds to a minute
- ◯ 1-2 min
- ◯ 2-3 min
- ◯ 3-4 min
- ◯ 4+ min

3. I think that the time it takes to identify the cause of alarms is: *

Mark only one oval.

- ◯ Adequate
- ◯ Sometimes too long
- ◯ Too long

4. Do you think alarms relating to major issues on board should be standardized * (Distinct specific alarms for specific systems)

Mark only one oval.

- ◯ Yes
- ◯ No

5. Do you think Aural warnings (short pre-recorded announcement) such as "Gyro-Compass fail" or "Generator 2 fire" would be a good form of alarm to have on the Bridge/ECR *

Mark only one oval.

- ◯ Yes
- ◯ No

6. Do you think it is necessary to have a binder or computer containing basic checklists for emergency procedures ("mini SMS") available on the Bridge/ECR for reference in case of non-normal occurances, emergencies. *

Mark only one oval.

- ◯ Yes
- ◯ No


7. Any comments concerning the above?

This content is neither created nor endorsed by Google.

Google Forms

4 Quantitative research, all comments

- The voice might help at first but later be annoying.
- 1 aspect to consider: When joining a new vessel it is not possible to familiarize with alarms before these accure. Meaning before incident or case really happens..
- A physical binder is more efficient for checklists in an emergency, also laminated lists with a dry wipe pen is even better. Bonus point is that it cannot fail as electrical systems (computers) could.
- Standardization of all alarms is near impossible due to the amount of different systems onboard different types of vessels, but the most important ones concerning f.ex. ecdis, gyros, gps, radars should be standardized
- no
- I think more modern technologies and transformation of the Bridge control systems will improve the Identification of alarm’s safety measures to be taken in ample time.
- Hard to give answer because different alarms take different amount of time to find/solve. Also some alarms are less important than others so just alarms in general can take between 10sec to one day to figure out depending on the severity of it. On a normal day you can easily get 10-20 alarms and probably most of them are something that people onboard knows about already and they basically just gets resetted and all back to normal. That's why these questions can be hard to answer because the time frame to find out is very dependet on what kind of alarms and the severity.
- Most cruiseships have these very specific alarms in place aswell on the bridge not only in the ECR
- Aural warnings are a good idea based on which system they represent. DP excellent. UMS no so good. As often more alarms comes in the same time.
- The alarm systems are usually fine and one should familiarize themselves with different systems when on the bridge. Things could be made easier but I do not see it as crucial and ships should not have to immediately change everything but rather work their way into new systems. For the voice alarm system, that would be good as long as you can mute the voice in order not to distract you or whoever you are speaking with on the intercom/radio etc
- Improvements are always welcome
- ECR automation processes are much more complicated to follow and solve during a fault situation when compared to the issues occurring only at the bridge or CCR. Engineers have better checklists but still need more time inorder to rise up a system again.

5 Comment

Thanks to all who contributed to this study by supervising, taking part in interviews, helping create the prototype, taking part in simulator runs, and filling out the questionnaire!