



ALARM MANAGEMENT

**Fundamentals
and Industry
Challenges**



1
Installment

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INTRODUCTION

Alarms are both mandatory and indispensable across both the maritime and offshore sectors, serving as critical tools that alert operators to deviations from standard operating conditions. These systems are essential for helping ensure safety, protecting assets and maintaining operational continuity. By providing clear, audible and visual alerts, alarms give operators the situational awareness needed to understand and respond effectively to potential issues, such as fire hazards, machinery malfunctions or navigational deviations.

The types of alarms on board can vary significantly depending on the vessel or asset type. For example, passenger ships are typically equipped with alarms designed to help passengers find muster stations or evacuate during emergencies. Alarms found on both passenger vessels and traditional commercial vessels can include fire, flooding and equipment failure alarms.

Regardless of the vessel type, alarms promote prompt and effective responses to reduce the risk of accidents, injuries and environmental damage. For instance, containerships have alarms which are specifically designed for cargo monitoring and lashing operations. Offshore assets, such as drilling rigs and production platforms, are equipped with unique alarm systems for well-control and environmental monitoring. Across all industries, alarms are not just signals; they are the cornerstone of operator understanding, helping to enable timely and informed decisions to prevent accidents or disruptions.

Modern alarm systems can contribute to enhanced safety, efficiency and scalability. However, the emergence of digitalization and advanced technologies is increasing complexity. These trends are introducing challenges such as cybersecurity risks, high costs, system integration complexities and crew inexperience with new technologies. Standards such as ISA 18.2 and IEC 62682 [1, 2] emphasize the need for a clear alarm philosophy to address these challenges. This philosophy establishes principles and criteria for alarm prioritization, configuration and management, helping to ensure alarms remain meaningful and actionable tools rather than sources of distraction.

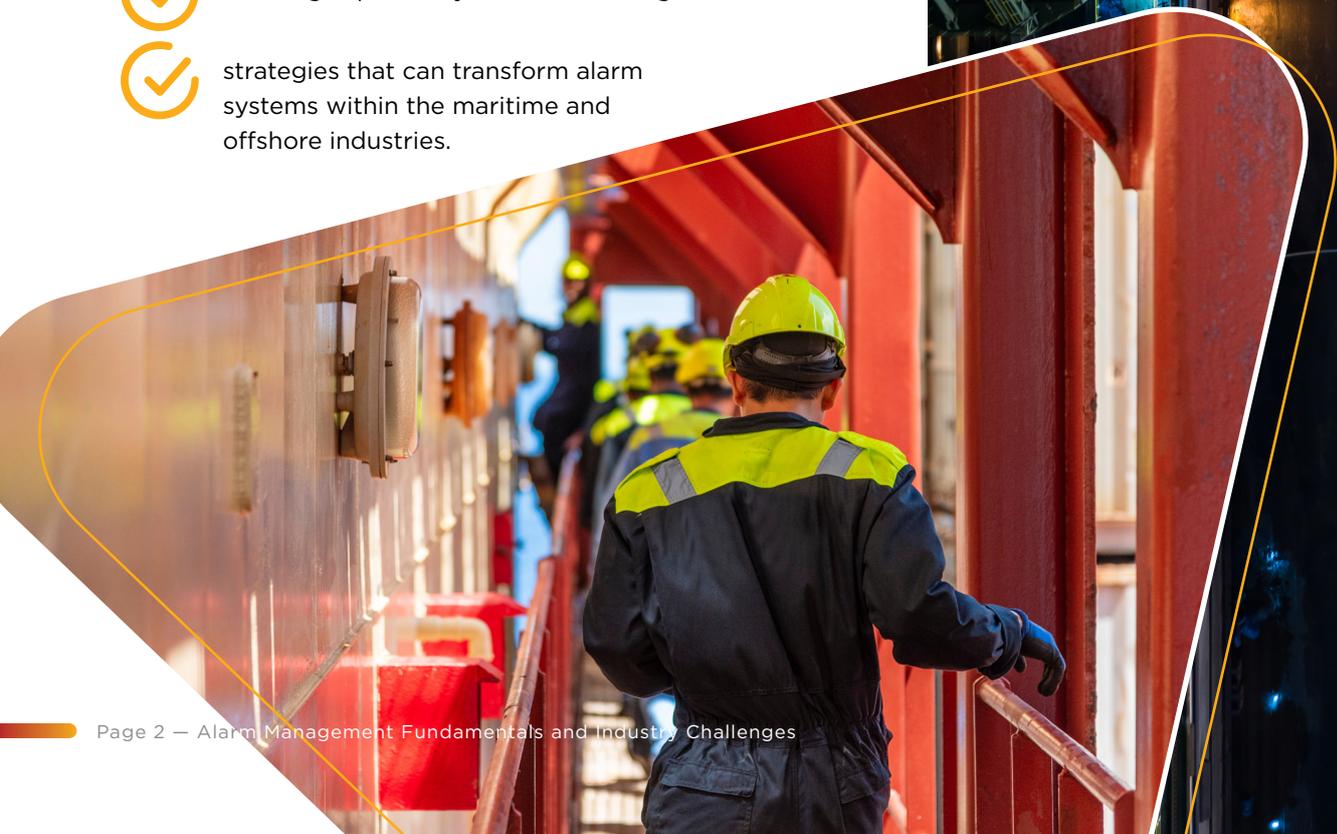
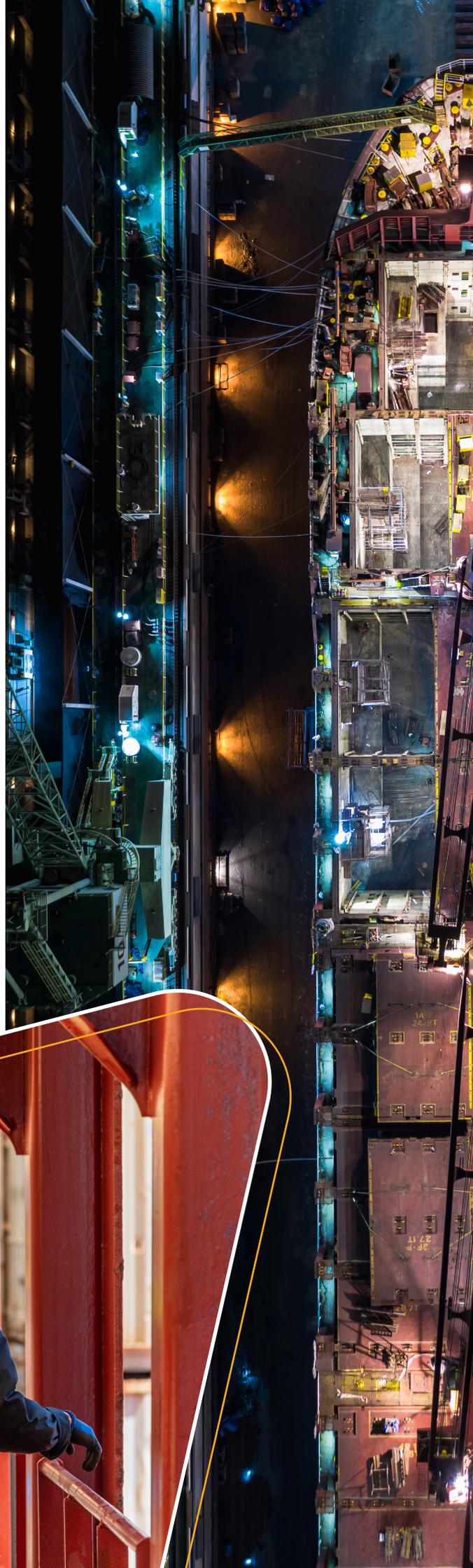


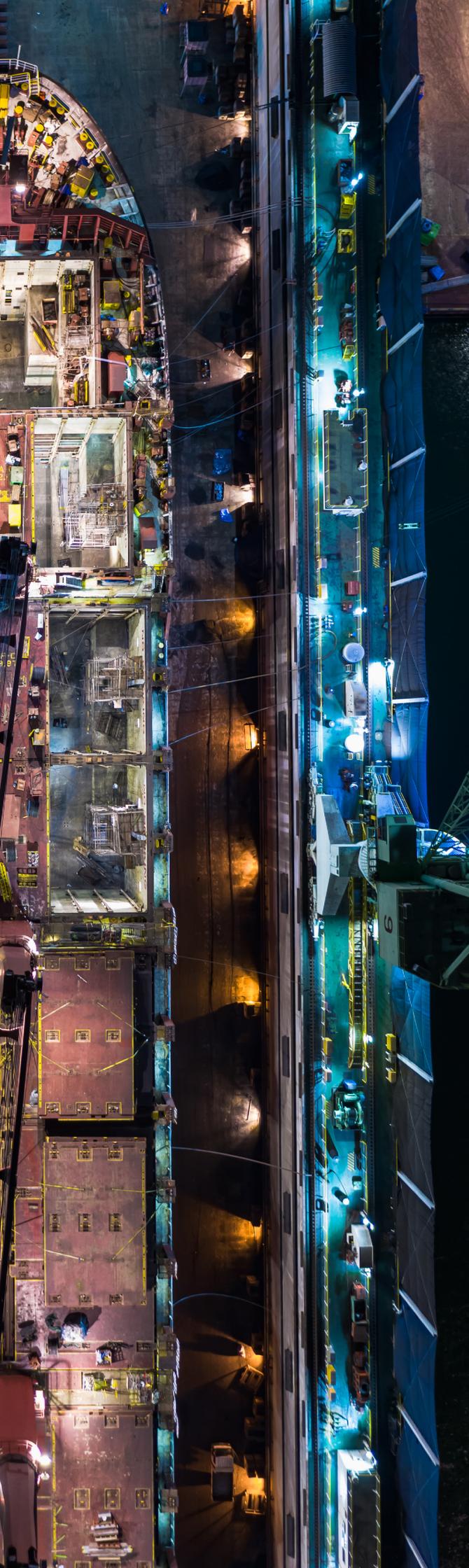
Alarm flooding, caused by poor system design or excessive configuration, can lead to alarm fatigue, reduced situational awareness and slower responses to critical alerts. These issues are intensified by alarm overloading, spurious alarms and periodic alarms, which further overwhelm crew members and can reduce the effectiveness of alarms as decision-making tools. In cruise ship environments, these challenges can significantly impact operations negatively by causing unnecessary stress for the crew and anxiety among passengers. Implementing a structured alarm philosophy, as discussed in ISA 18.2 and IEC 62682 [1, 2], helps organizations mitigate these risks through proactive alarm rationalization and prioritization, helping to enable safer and more efficient operations.

The integration of artificial intelligence (AI) and machine learning (ML) into alarm systems holds potential for addressing persistent challenges. These technologies can help filter and prioritize alerts based on real-time data, directing attention to critical alarms while easing the cognitive workload on crew members. They can help reduce false alarms, enable predictive maintenance and adjust alarm thresholds based on changing conditions. Emerging industry applications are exploring real-time analytics, decision-support systems and adaptive algorithms as steps toward improving alarm functionality. Such innovations have the capacity to enhance human-system relationships onboard, contributing to improved safety and operational efficiency.

This document emphasizes the importance of supporting and empowering the crew to help promote safer operations. It explores:

- ✓ regulatory standards governing alarm systems,
- ✓ challenges posed by alarm mismanagement and
- ✓ strategies that can transform alarm systems within the maritime and offshore industries.





STANDARDS, GUIDELINES AND INDUSTRY PRACTICES

Alarm management has long been recognized as a critical issue for onboard personnel, with the potential to impact both safety and operational efficiency. To address these challenges, several maritime bodies and industry publications have established guidelines for alarm systems and their management.

The International Maritime Organization (IMO) Resolution MSC.302(87) [3] titled “Performance Standards for Bridge Alert Management,” emphasizes the importance of alarm clarity, conciseness and prioritization, while encouraging system integration to minimize distractions for the crew. Similarly, the IMO Resolution A.1021 (26) [4], titled “Code on Alerts and Indicators,” highlights the need to establish procedures for alarm management and underscores the value of training and drills to ensure crew readiness. The ISM Code [5] further reinforces these principles, requiring documented procedures for alarm management and emphasizing the role of training and drills in maintaining operational safety.

Additionally, SOLAS Regulations V/19 and II-1/48 provide generic guidance on alarm systems, serving as foundational frameworks for industry practices [6]. Together, these standards and regulations form the backbone of alarm management protocols, offering a structured approach to enhancing onboard safety and efficiency.

Beyond these standards, additional publications have expanded the scope of alarm management, addressing critical aspects of system design and integration. The International Association of Classification Societies (IACS) Unified Requirement E22, titled “Onboard Use and Application of Computer-Based Systems,” underscores the importance of alarms being both reliable and user-friendly, while ensuring systems are fail-safe to prevent catastrophic failures [7].

The International Electrotechnical Commission (IEC) 62682, “Alarm Management for the Process Industries,” provides detailed guidance on alarm rationalization and performance monitoring, offering a framework to optimize alarm systems and enhance their operational effectiveness. Complementing these, the IEC 61162 series focus on the integration of navigational and communication equipment, ensuring seamless interoperability between systems to support crew decision-making. Together, these publications provide a comprehensive approach to alarm management, addressing technical, procedural and integration challenges to further strengthen onboard safety and efficiency [2].

IMO

SOLAS

IACS

IEC

ABS publications also play a vital role in defining alarm management requirements to help ensure onboard operations meet the ABS Rules. The ABS Marine Vessel Rules (MVR), Part 6, Chapter 9, require that alarm systems must be prioritized, designed to prevent flooding, and subjected to regular testing and maintenance [8]. The ABS Guide for *Bridge Design and Navigational Equipment/Systems* further addresses the functionality requirements for bridge design and layout, supported by associated ABS notations such as NBL, NBLES, NBLES+, and NIBS [9].

Additionally, the ABS *Guidance Notes for the Ergonomic Design of Navigation Bridges* provides vessel and equipment designers with ergonomic principles and data to help improve navigation bridge design [10], complementing the ABS *Guide for Bridge Design*. Similarly, the ABS *Guidance Notes on the Application of Ergonomics to Marine Systems* focus on general alarm systems, control displays and their integration to enhance usability and safety [11].

While these standards are fundamental in establishing baseline safety and ensuring regulatory compliance, classification societies have traditionally prioritized adherence to minimum requirements. This approach provides consistency and reliability across the industry, though it may not always incentivize the exploration of more advanced or optimized methodologies in alarm system design and management.



▲ CHALLENGES IN ALARM MANAGEMENT

Alarm mismanagement has contributed to many maritime disasters, leading to loss of life, damage to vessels and harm to the environment. Operations at sea have long been hindered by failures in alarm systems, which can impede timely and effective responses to escalating conditions. Sometimes these challenges can be compounded when common sensors are shared between alarm management systems and optional monitoring systems (e.g., automatic slow-downs or shutdowns). This overlap can result in unintended automatic reactions, such as machinery slowing down or shutting off during critical moments, which can limit the response time for the crew to override or bypass these systems during emergencies.

CASE STUDIES

During the **Piper Alpha Disaster (1988)** [12], insufficient gas leak warnings, escalating conditions and alarm overload overwhelmed the crew and hindered their ability to respond effectively, prompting significant changes in offshore alarm management regulations [13].

The **Costa Concordia Grounding (2012)** [14] highlighted the risks of poor alarm prioritization and system design, as navigation alarms failed to sufficiently alert the crew to the vessel's deviation from its planned course, delaying corrective actions and contributing to the disaster.

More recently, the **Viking Sky Incident (2019)** [15] illustrated how alarm flooding can worsen ongoing challenges during critical situations. As the cruise ship experienced engine failures while navigating treacherous waters, excessive alarms overwhelmed the crew and complicated their response efforts, highlighting gaps in alarm rationalization during emergencies. These incidents serve as clear reminders of the importance of reliable alarm management systems in protecting lives, vessels and the environment.

Alarm mismanagement remains a critical challenge, with issues such as alarm overload, suppressed alarms, poor system integration and insufficient consideration of human factors undermining onboard safety and efficiency. Excessive alarms overwhelm operators, leading to missed critical warnings, while inhibited alarms and fragmented systems hinder situational awareness and timely responses.

The rise of innovative technologies in the maritime sector has introduced challenges such as technostress, stemming from difficulties in adapting to and effectively using new systems. This, combined with traditional stressors like social isolation and long periods away from home, increases the cognitive workload of mariners, potentially leading to alarm fatigue, operator overload, reduced situational awareness and delays in responding to critical events [16, 17].

Addressing these challenges requires prioritizing human factors in system design, helping to ensure alarms are streamlined, actionable and supportive of crew decision-making.

As the maritime industry embraces innovation through autonomy and artificial intelligence, optimizing alarm management methodologies is essential to safeguard mariners, vessels and the environment.



▲ STRATEGIES FOR EFFECTIVE ALARM MANAGEMENT

Effective alarm management is a cornerstone of safe and efficient operations. The increasing complexity of modern vessels and the proliferation of alarms have introduced significant challenges, including alarm fatigue, mismanagement and the need for seamless integration with new and emerging technologies. Addressing these challenges requires an integrated approach that combines technical innovation, human-centered design and robust training programs.

KEY STRATEGIES INCLUDE:



Alarm Filtering and Prioritization

Advanced technologies such as AI and ML can filter out irrelevant or redundant alerts, presenting only the most critical information to the crew. This reduces cognitive workload, enhances situational awareness and helps ensure that crew members can focus on addressing genuine issues. Alarm prioritization highlights the most critical alerts for immediate attention, enabling prompt decision-making during emergencies.



Integration of Human Factors

Alarm systems must align with the cognitive and physical capabilities of the crew. Human-centered design principles, such as intuitive interfaces and adaptive learning systems, enhance usability and reduce alarm fatigue. Human performance modeling can predict and mitigate alarm fatigue, helping ensure operators stay alert and responsive.



Training and Simulation Tools

Comprehensive training programs, including simulation-based and virtual reality (VR) tools, can prepare crews to manage alarms effectively. These tools help improve technical proficiency, build confidence, and help operators understand the logic and functionality of alarm systems.



Leveraging Emerging Technologies

AI, ML and Internet of Things (IoT) devices can provide predictive insights, real-time filtering and adaptive alarm thresholds, transforming alarm systems from reactive to proactive tools for safety and efficiency.



▲ CONCLUSION

Alarm management is a multifaceted challenge, shaped by evolving technology, human factors and rigorous regulatory standards. To truly advance safety and operational excellence, it's essential to examine each aspect in greater detail. In the following issues, we'll take a closer look at the most pressing matters and explore practical strategies for overcoming these challenges by leveraging technological advancements.

▲ NEXT INSTALLMENT

In the next installment, we will take a deep dive into the most pressing operational challenges facing industrial facilities today: alarm fatigue, alarm flooding and alarm prioritization. We will explore how excessive alarms impact operator focus, how poor system design leads to alarm floods during critical events, and how prioritization that is driven by regulations and technology can restore control room effectiveness.



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1701 City Plaza Drive | Spring, TX 77389 USA
1-281-877-6000 | www.eagle.org

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