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Distress Tracking and Safety Communications in Aviation and Maritime Domains – A Comparative Analysis of GADSS and GMDSS

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Abstract

The article presents a comparative analysis of the Global Aeronautical Distress and Safety System (GADSS) and the Global Maritime Distress and Safety System (GMDSS), which are used to support safety operations in the aviation and maritime sectors. Particular attention is devoted to distress tracking architectures, emergency communications, search and rescue support, and information management under emergency conditions. The study examines the characteristics of normal tracking, distress tracking, distress alerting, search and rescue coordination, and information dissemination within aviation and maritime environments. It also analyzes approaches to distress condition determination, the role of CONOPS documents and ARINC 680 in the evolution of GADSS, as well as the regulatory framework and operational logic underlying GMDSS. The findings demonstrate that the aviation and maritime sectors employ different operational paradigms for distress response. GADSS is built around autonomous object tracking and the early detection of emergency situations, whereas GMDSS is centered on the transmission of distress information and the coordination of communication among participants in rescue operations. The principal outcome of the study is the development of the author's Integrated Distress Tracking and Safety Communication Framework, which integrates event detection, object tracking, information transmission, data management, satellite interaction, search and rescue coordination, and decision support within a unified analytical structure. The proposed model enables comparative analysis of aviation and maritime safety systems based on common functional layers while preserving the distinctive characteristics of each domain.

Keywords: *Aviation Safety, Maritime Safety, Object Tracking, Emergency Communications, Distress Signals, Search And Rescue Operations, Satellite Surveillance.*

INTRODUCTION

Aviation and maritime transport employ different approaches to safety assurance. However, in both domains, the success of a search and rescue operation largely depends on how quickly the location of an aircraft or vessel can be determined after an emergency occurs [14]. When contact with an aircraft or ship is lost, every minute increases the search area and reduces the likelihood of timely assistance. Consequently, increasing attention has been devoted in recent years to continuous position monitoring, automatic detection of distress indicators, and rapid information exchange among the vehicle control services, and search and rescue coordination centers.

To address these challenges, civil aviation has been developing the Global Aeronautical Distress and Safety System (GADSS), while maritime transport relies on the Global Maritime Distress and Safety System (GMDSS). GADSS is focused on continuous aircraft tracking and the automatic transmission of position data when distress conditions are detected. In contrast, GMDSS is primarily based on the transmission of distress alerts and the establishment of communication among participants involved in search and rescue operations [6]. Although both systems pursue similar safety objectives, they emphasize different elements of safety management. GADSS concentrates on tracking the object, whereas GMDSS focuses on distress communications and the coordination of information exchange.

The aim of this study is to develop an integrated comparative model for analyzing distress tracking and safety communication architectures in aviation and maritime transportation based on the GADSS and GMDSS frameworks. To achieve this objective, the following tasks are addressed:

– to analyze the operational architecture of GADSS;

– to analyze the operational architecture of GMDSS;

– to compare aviation and maritime approaches to object

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tracking, distress alert generation, and support for search and rescue operations;

– to identify areas of technological convergence and differences in the development of safety systems in the two transport domains.

The research hypothesis is that the differences between GADSS and GMDSS are determined not so much by the communication technologies employed as by fundamentally different approaches to distress response. In aviation, priority is given to continuous tracking of the aircraft, whereas maritime transport places greater emphasis on the transmission of distress information and the establishment of communication links. Advances in satellite monitoring and digital data exchange technologies are gradually bringing these approaches closer together, fostering the development of more integrated safety systems.

The scientific novelty of this study lies in the joint analysis of GADSS and GMDSS, which are typically examined separately. Particular attention is given to the distinction between object tracking and distress message transmission as two different mechanisms for responding to emergency situations. The principal outcome of the study is an original analytical model that integrates the key elements of aviation and maritime safety architectures within a unified conceptual framework.

MATERIALS AND METHODS

This study was conducted as a review-based analytical investigation followed by the development of an original comparative model for analyzing Distress Tracking and Safety Communication systems in the aviation and maritime domains. The analysis included publications published between 2022 and 2026 addressing GADSS, GMDSS, aircraft and maritime object tracking, emergency communications, satellite data transmission, search and rescue operations, and digital transportation safety technologies.

The literature search was performed using Google Scholar, SpringerLink, MDPI, and other open-access scientific resources. The following keywords and combinations were used: "GADSS," "Global Aeronautical Distress and Safety System," "GMDSS," "Global Maritime Distress and Safety System," "distress tracking," "aircraft tracking," "safety communications," "maritime safety communications," "search and rescue," "SAR," "ADS-B," "AIS," "NAVTEX," "Inmarsat," "VDES," "satellite communications," "distress alerting," "emergency communications," "aviation safety," and "maritime safety." The search process was refined through the use of the Boolean operators AND and OR. Publications containing technical, operational, analytical, or methodological information related to GADSS, GMDSS, or associated tracking and emergency communication technologies were included. Studies that did not address object tracking, distress information transmission, or search and rescue support were excluded.

At the initial stage, 37 publications were identified. Following an assessment of relevance, full-text availability, and compliance with the objectives of the study, 15 sources were selected for the final analysis. These materials were used to examine the operating principles of GADSS and GMDSS, analyze the communication and surveillance technologies employed within these systems, and compare aviation and maritime approaches to safety management.

The methodological framework of the study was based on comparative analysis, functional analysis of safety systems, and synthesis of findings. The comparison of GADSS and GMDSS was conducted across several dimensions, including object tracking, distress detection, emergency information transmission, support for search and rescue operations, data management, and geographical coverage. The findings obtained formed the basis for the development of an original model integrating the principal components of aviation and maritime safety architectures.

The main limitation of the study is associated with the heterogeneity of the reviewed sources. The publications differ in terms of their objects of analysis, level of technical detail, types of data, and research objectives. Nevertheless, the collected material provides a sufficient basis for comparing GADSS and GMDSS and for developing an original comparative analytical framework.

RESULTS

Following the comparison of GADSS and GMDSS, it becomes evident that the differences between the two systems emerge even before a distress signal is transmitted. In the maritime sector, the starting point is typically the transmission of a distress alert through established communication channels. Aviation follows a different logic. With the introduction of GADSS, primary attention shifted toward the earliest possible detection of distress conditions and the preservation of continuous awareness of an aircraft's location. The same objective—reducing the search area—has therefore resulted in the development of two distinct safety paradigms [12].

This distinction is particularly evident in normal tracking operations. In aviation, aircraft surveillance is a continuous process. Position, altitude, speed, and other flight parameters are constantly transmitted to the system and used to maintain an up-to-date operational picture of the aircraft's movement [13]. Maritime transport evolved along a different trajectory. GMDSS was originally designed as an emergency communication system. Continuous monitoring capabilities emerged later and developed separately through systems such as AIS, LRIT, and other vessel traffic monitoring tools [9]. As a result, tracking functions and distress communication functions remained separate components of the maritime safety infrastructure for a considerable period of time.

The differences become even more apparent when examining distress tracking. Following the AF447 and MH370 disasters, locating an aircraft was no longer viewed solely as a task for search and rescue services. It became an integral part of the safety architecture itself. GADSS is based on the assumption that, once indications of distress emerge, the system should continue transmitting position information even if some conventional surveillance capabilities become unavailable. Consequently, the issue extends beyond the reliability of the communication channel alone. Equally important is the ability to maintain continuous and reliable information about the movement of the aircraft under conditions where new data may be limited or disrupted [1]. The maritime model follows a different logic. The primary event is the receipt of a distress alert, after which procedures for position determination and search and rescue coordination are initiated [15].

The issue of distress condition determination deserves separate consideration. During the early stages of GADSS development, the CONOPS documents did not establish a unified mechanism for identifying emergency situations. Equipment manufacturers were allowed to define their own criteria for switching into distress mode. While this approach facilitated system implementation, it also resulted in significant variation among different implementations. The situation changed with the introduction of ARINC 680. The standard established a more formalized approach to distress detection and linked it directly to the operational requirements of onboard systems.

This development addressed one of the most challenging practical issues within the entire GADSS architecture. The existence of a position-reporting channel alone does not solve the problem. The system must determine the precise moment at which a normal flight transitions into a distress phase. After the AF447 and MH370 accidents, this issue ceased to be a purely theoretical concern. Without a clearly defined mechanism for identifying a distress condition, even continuous tracking cannot guarantee a timely response. At the CONOPS stage, no common criteria existed. Different manufacturers could rely on their own parameter sets and decision-making logic. ARINC 680 substantially reduced the scope for such variations. As a result, distress recognition was shifted from the domain of operational interpretation into the domain of architectural and certification requirements [11].

Support for search and rescue operations is also organized differently in the two domains. In aviation, a significant portion of the information required for a subsequent search is accumulated before an emergency occurs. By the time the system enters a distress phase, it already possesses data on the planned route, flight parameters, and the aircraft's last known position. In maritime transport, most information activity begins after the registration of a distress event. Coastal coordination centers, satellite services, and Maritime Safety Information dissemination channels are then activated to support the response process [7]. In one case, the primary emphasis is placed on reducing uncertainty before the search operation begins. In the other, the focus is on delivering distress information to all participants in the rescue effort as rapidly as possible.

Information Management is of particular interest because the differences between GADSS and GMDSS become less pronounced in this area. The maritime system is no longer limited to the transmission of distress alerts through radio communication channels. It now incorporates satellite services, digital data-exchange platforms, global vessel-tracking capabilities, and mechanisms for distributing information among multiple participants within the maritime infrastructure [5]. A similar transformation is occurring in aviation. Surveillance data are used not only to determine the location of an aircraft. They also support trajectory analysis, identification of deviations from normal flight profiles, and detection of indicators associated with potentially hazardous developments [10]. As a result, both systems increasingly operate on the basis of continuous data streams that support decision-making at multiple levels of management. Table 1 presents the radio-frequency characteristics of technologies used for surveillance and data transmission in contemporary aviation and maritime safety systems.

Table 1. Radio Frequency Parameters of Satellite Monitoring Systems Used in Aviation and Maritime Domains (Compiled by the author based on data from source: [2])

Channel	Band	Frequencies	Transmitted Data
AIS	VHF	156.775 MHz; 156.825 MHz; 161.975 MHz; 162.025 MHz	Vessel identity, position, speed, course
ADS-B	UHF	978 MHz; 1090 MHz	Aircraft identity, intent, position, speed, altitude
CubeSat Radio Communication	Radio Spectrum	3 kHz–300 GHz	Satellite communication, telemetry, tracking and command
CubeSat Optical Communication	Optical Spectrum	300 GHz–10^{12} GHz	High-speed data transmission

At first glance, ADS-B and AIS appear to be technologies designed for entirely different transportation environments. However, the differences between them become less significant when examined from the perspective of their functional role. In both cases, the objective is the continuous acquisition of information regarding an object's position and movement. The systems differ in operating frequencies, the composition of transmitted data, and operating conditions, but their fundamental purpose remains the same. The development of satellite-based infrastructure has further increased their similarity. Modern satellite constellations are capable of simultaneously receiving AIS and ADS-B signals, providing surveillance coverage over oceans, polar regions, and other areas where terrestrial monitoring capabilities are limited.

The differences become more apparent when geographical coverage is considered. Within GMDSS, the world's oceans are divided into sea areas A1–A4. Each area is associated with a specific set of communication technologies determined by the availability of coastal and satellite services [7]. Aviation follows a different approach. For GADSS, the key requirement is the preservation of aircraft position information throughout the entire route. This is particularly important in oceanic and remote regions where conventional surveillance capabilities are limited. Under such conditions, satellite infrastructure becomes not merely a supplementary component but an essential element of the system.

Significant differences also remain within the regulatory framework. Aviation safety architecture has evolved around requirements for distress detection, data transmission, and onboard system performance. ARINC 680, TSO-C126b, and DO-204B/ED-62B serve precisely this function [1]. In the maritime sector, the regulatory logic is structured differently. SOLAS and Title 47 Part 80 Subpart W primarily define equipment requirements, communication channel availability, and procedures for transmitting distress alerts [7]. The distinction is evident even at the level of regulatory objectives. In one case, emphasis is placed on identifying emergency situations and preserving surveillance data. In the other, priority is given to ensuring reliable delivery of distress messages through available communication networks.

The most significant developments of recent years are associated with the growing role of data processing. Earlier generations of aviation and maritime safety systems were primarily designed to transmit information to human operators. Today, data is increasingly integrated into automated processing environments. Their function is no longer limited to notifying personnel about an event. Instead, they have become an integral component of risk detection and decision-support mechanisms.

In aviation, this transition is clearly illustrated by ADS-B. The technology was originally developed for air traffic surveillance. Today, the same data are employed for trajectory analysis, detection of deviations from normal flight profiles, and automated identification of potentially hazardous situations [3]. Surveillance is gradually evolving into an instrument of early warning.

A similar transformation is taking place in the maritime sector through the modernization of GMDSS. NAVTEX, AIS, VDES, Global Ship Tracking systems, and satellite services increasingly operate as components of a unified information environment [7]. The primary focus is shifting from the transmission of individual messages toward the provision of continuous data exchange among vessels, satellite infrastructure, coastal authorities, and search and rescue coordination centers. Table 2 presents a comparison of methods used for the recovery of corrupted NAVTEX messages.

Table 2. Performance Comparison of NAVTEX Message Recovery Methods (Compiled by the author based on data from source: [4])

Recovery Method	Average Recovery Accuracy (%)	AUC	Processing Time (ms)
MLM (Transformer)	85.4	2889	19.30
Five-gram	64.0	2007	5.20
Four-gram	59.1	1862	4.17
Dictionary Matching	58.6	1832	334.77
Tri-gram	44.4	1408	5.63

The difference between the methods presented extends beyond purely technical performance indicators. The underlying approach to handling distress information is also changing. In the past, a corrupted message was often regarded as partially or completely lost. Modern algorithms make it possible to reconstruct a substantial portion of its content before the information reaches the operator. As these solutions continue to evolve, system resilience becomes increasingly less dependent solely on the characteristics of the communication channel. Greater importance is now attached to the ability of software systems to extract and reconstruct information from incomplete or corrupted data.

The same trend can be observed in emerging GMDSS development initiatives. VDES is increasingly viewed as an environment for continuous data exchange among vessels, coastal authorities, satellite platforms, and search and rescue organizations. Similar functions are beginning to be performed by Inmarsat networks and multilayered architectures integrating satellite, terrestrial, and future 5G/6G communication components [8]. As these technologies evolve, the boundaries between communication, surveillance, data exchange, and search and rescue support are becoming progressively less distinct.

The comparison demonstrates that the convergence of GADSS and GMDSS is occurring primarily at the technological level. Both systems are making increasing use of satellite networks, digital data exchange, and automated information processing. However, their underlying operational logic remains fundamentally different. In aviation, the process begins with continuous surveillance of the aircraft and the detection of distress indicators. In the maritime domain, the starting point remains the transmission of a distress alert followed by the coordination of communication among participants in the rescue operation. This distinction continues to define the differences between the two architectures, even as both systems move toward increasingly digital and data-driven models of information management.

DISCUSSION

The aviation and maritime sectors address the same fundamental challenge: reducing the time between the onset of a distress event and the initiation of rescue operations. However, the underlying logic of these systems differs. The decisive factor is the point at which the system begins to respond to the development of an emergency situation. For this reason, GADSS and GMDSS should be viewed primarily as two distinct models of safety management.

Following the AF447 and MH370 disasters, aviation faced a problem that had previously remained largely in the background. It was no longer sufficient simply to know where to search for an aircraft after an accident. A new requirement emerged: determining the moment at which the system itself should recognize the transition from normal flight to a distress situation and initiate the transmission of distress-related information. The GADSS concept gradually evolved around this challenge.

This explains the central role of distress tracking within the aviation safety architecture. If distress is recognized too late, the value of continuous surveillance is significantly reduced. If it is recognized too early, the number of false alerts increases and additional burdens are placed on the surveillance infrastructure. The primary concern is therefore not the transmission of position data itself, but the decision point at which the system determines that the flight is no longer proceeding under normal conditions.

During the CONOPS development stage, no unified solution to this problem existed. Neither the specific onboard system responsible for recognizing a distress condition nor a universal set of parameters for making such a determination had been defined. Manufacturers were therefore allowed to develop their own distress-detection logic. For the aviation industry, this created the possibility of multiple, potentially different approaches to interpreting the same operational events. Identical indicators could trigger different system responses depending on the architecture selected.

The introduction of ARINC 680 changed this situation. The significance of this document is primarily associated with its attempt to formalize the very mechanism by which a system transitions into distress mode. An issue that had previously belonged largely to the domain of operational practice was elevated to the level of architectural requirements. In this sense, ARINC 680 represents far more than just another technical standard. Its role is considerably broader. It established common decision-making principles at one of the most critical points within the entire GADSS concept.

The maritime sector approached the same challenge through a different path. GMDSS was originally designed around the provision of emergency communications among participants in a search and rescue operation. The principal challenge was ensuring that distress information reached those who needed to respond to it. For this reason, the role of the operator remains significant even after extensive digital modernization of the system. The transmission of a distress alert, confirmation of its receipt, and subsequent coordination of rescue activities continue to occupy a central position within the architecture. As a result, aviation and maritime safety systems address the same problem from different perspectives: the former seeks to detect distress earlier, while the latter aims to disseminate distress information more rapidly.

The ongoing evolution of GADSS and GMDSS demonstrates that the differences between them are increasingly less defined by individual technical solutions. Greater importance is now attached to the processing and utilization of information after it has been received. Information transmission is no longer viewed as the final outcome of system operation. Instead, attention has shifted toward the subsequent use of that information.

In aviation, surveillance data have long ceased to serve a purely navigational function. Information regarding aircraft movement is used to identify deviations from normal flight profiles, detect atypical behavior, and support operational decision-making. A similar transformation is taking place in maritime transport. Safety messages are increasingly becoming part of an integrated digital environment in which information can be automatically processed, correlated, and exchanged among multiple services without direct operator involvement.

As these developments continue, the distinction between tracking and communication becomes progressively less apparent. Surveillance technologies are increasingly used for information transmission, while communication systems simultaneously contribute to the creation of an operational picture of object movement. This trend is particularly evident in VDES initiatives, next-generation satellite services, and modern data-exchange platforms. Within such architectures, surveillance, communication, and information management can no longer be viewed as entirely independent functions.

The transformation also affects the methods used to analyze incoming information. The volume of available data continues to increase, while the capacity for manual processing remains inherently limited. Consequently, an increasing number of tasks are being delegated to automated analytical algorithms. These systems are employed to identify anomalies, assess potential risks, and detect indicators of adverse developments. Whereas earlier generations of safety systems primarily reacted to events that had already occurred, contemporary digital solutions are increasingly focused on identifying their early precursors. As a result, the boundary between distress detection and distress prediction is gradually becoming less distinct. Figure 1 presents the integrated model for the analysis of aviation and maritime safety systems developed by the author.

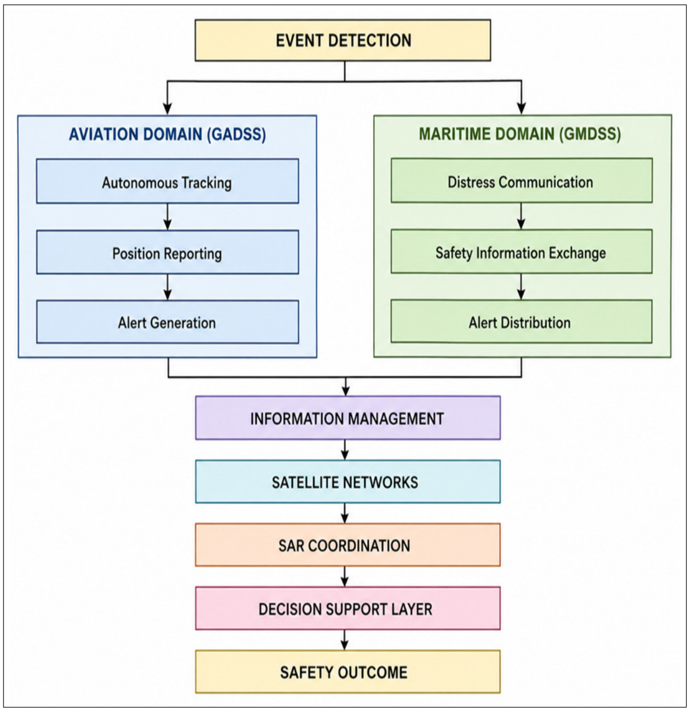

Figure 1. Integrated Cross-Sector Model of Distress Tracking and Safety Communications in Aviation and Maritime Transport (Developed by the Author)

The proposed model is based on the assumption that the principal differences between GADSS and GMDSS emerge at the very beginning of the safety assurance process. For this reason, the framework starts with a common Event Detection block, after which the process diverges into two independent pathways.

Within the aviation architecture, the subsequent sequence of actions is built around object tracking. In GADSS, surveillance serves as the starting point for the entire response chain. The maritime system follows a different logic. Here, the first step is the transmission of distress information and its subsequent dissemination among participants involved in search and rescue operations.

The most significant developments occur after this initial stage. Despite their different starting points, both systems gradually converge toward similar functional layers. Information enters an information-management environment, is transmitted through satellite infrastructure, and is subsequently used to coordinate search and rescue activities. The next layer is concerned not with information transmission itself but with information interpretation and decision support. It is at this stage that the differences between aviation and maritime architectures become considerably less pronounced.

The model does not view GADSS and GMDSS as competing solutions. Nor does it assume their eventual integration into a single unified system. The findings of the study suggest a different interpretation. Both architectures address a similar challenge but approach it from different directions. In aviation, the primary objective is the timely detection of distress indicators. In maritime transport, the priority is the rapid dissemination of information after a distress event has occurred. As digital technologies continue to evolve, this distinction remains concentrated largely at the initial stage of the process. Beyond that point, both systems increasingly rely on similar mechanisms for data management, satellite communications, and decision support.

The proposed model makes it possible to examine aviation and maritime safety systems within a unified analytical framework while preserving the distinctive characteristics of each domain. This approach enables direct comparison of the two architectures across equivalent functional levels without artificially merging or contrasting two inherently independent systems.

CONCLUSION

The analysis demonstrated that the differences between GADSS and GMDSS do not emerge at the stage of distress signal transmission but much earlier—at the point where the safety process itself is initiated. In aviation, the central role is played by the detection of distress indicators and the subsequent tracking of the aircraft. In maritime transport, the foundation of the system remains the transmission of distress information and the organization of communication among participants in the rescue operation. This distinction is what fundamentally shapes the architecture of both systems.

The principal outcome of the study is the development of the author’s Integrated Distress Tracking and Safety Communication Framework. The model demonstrates that the greatest differences between aviation and maritime safety systems are concentrated at the initial stage of response. Once distress has been detected, both architectures increasingly rely on similar mechanisms for data management, satellite-based interaction, search and rescue coordination, and decision support.

The practical significance of the study is associated with the analysis of the distress condition determination problem within the GADSS architecture. Examination of CONOPS and ARINC 680 showed that system effectiveness depends not only on the transmission of position data but also on the ability to recognize, in a timely manner, the transition to a distress situation. For this reason, distress detection has become an independent element of the safety architecture rather than merely an operational procedure.

The proposed hypothesis has been confirmed. The findings indicate that GADSS and GMDSS address similar challenges through different operational paradigms. The former begins with object tracking, whereas the latter begins with the transmission of distress information. At the same time, the digital evolution of both architectures is leading to a gradual convergence of data-management and search-and-rescue support mechanisms while preserving the distinctive characteristics of each sector.

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