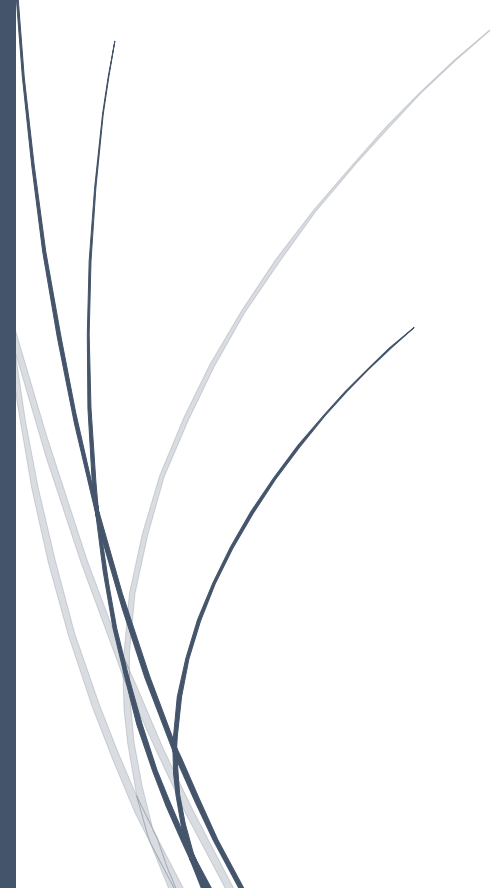


The logo for RADemics, featuring the text "RADemics" in white on a blue arrow-shaped background. The arrow points to the right and is part of a larger blue graphic element on the left side of the cover.

RADemics

Aircraft Accident Investigation Frameworks and International Aviation Safety Protocols

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Aircraft Accident Investigation Frameworks and International Aviation Safety Protocols

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Abstract

Aircraft accident investigation plays a pivotal role in strengthening global aviation safety by systematically identifying the technical, operational, human, and organizational factors responsible for aviation occurrences and translating investigative findings into effective preventive measures. Rapid advancements in aircraft automation, digital avionics, satellite-based navigation, integrated flight management systems, and intelligent communication technologies have significantly increased the complexity of modern accident investigations, requiring multidisciplinary approaches supported by internationally harmonized regulatory frameworks. This chapter presents a comprehensive review of aircraft accident investigation frameworks and international aviation safety protocols, emphasizing globally accepted practices established by the International Civil Aviation Organization (ICAO) and complementary regulatory organizations responsible for civil aviation safety. The discussion examines the evolution of accident investigation methodologies, international regulatory frameworks, evidence collection procedures, flight data acquisition, aircraft systems and component failure analysis, human factors assessment, organizational safety evaluation, and systematic accident reconstruction techniques. Contemporary analytical models, including fault-based, systems-oriented, and human reliability approaches, are examined to illustrate their contributions to identifying direct and latent safety deficiencies. The chapter further explores the integration of emerging technologies such as artificial intelligence, machine learning, digital twins, three-dimensional crash scene reconstruction, unmanned aerial systems, predictive analytics, and cloud-enabled collaborative investigation platforms that are transforming conventional investigative practices into intelligent, data-driven safety management systems. The strategic role of the Global Aviation Safety Plan (GASP), Safety Management Systems (SMS), State Safety Programmes (SSP), and international collaboration in establishing proactive risk management and continuous safety improvement is also critically discussed. Current challenges associated with highly automated aircraft, cybersecurity, digital evidence management, multinational investigations, and next-generation aviation systems are analyzed to identify future research opportunities.

Keywords: Aircraft Accident Investigation, International Civil Aviation Organization (ICAO), Aviation Safety Protocols, Flight Data Analysis, Safety Management Systems (SMS), Artificial Intelligence in Aviation Safety.

Introduction

The aviation industry has become one of the most sophisticated and reliable transportation systems in the world, supporting international commerce, tourism, humanitarian operations, and economic development across every continent [1]. Continuous advancements in aerodynamics, propulsion technologies, avionics, navigation systems, air traffic management, and aircraft manufacturing have substantially improved flight safety and operational efficiency over the past several decades. Commercial airlines transport billions of passengers annually while maintaining an exceptionally high level of operational reliability through strict regulatory oversight, standardized operational procedures, and continuous technological innovation [2]. The increasing demand for air transportation has also accelerated the development of highly automated aircraft, digital communication systems, satellite-based navigation, and integrated flight management technologies capable of enhancing flight precision and reducing operational risks. Such technological progress has transformed aviation into an essential component of modern society, connecting nations and supporting global economic growth [3]. Although accident rates have declined significantly compared with earlier decades, aviation accidents continue to represent high-consequence events because of the potential loss of human life, damage to expensive aircraft, disruption of transportation networks, environmental impacts, and long-term effects on public confidence. Every aviation occurrence provides valuable technical knowledge regarding aircraft performance, operational decision-making, maintenance effectiveness, and organizational safety practices [4]. Continuous learning from accident investigations has therefore become an indispensable strategy for strengthening aviation safety and preventing the recurrence of similar events. The effectiveness of global aviation safety depends not only on technological advancement but also on systematic investigation processes capable of identifying complex interactions among technical, operational, environmental, and organizational factors that influence aircraft operations [5].

Aircraft accident investigation has evolved into a multidisciplinary scientific process that integrates engineering principles, operational analysis, forensic science, human factors research, materials engineering, meteorology, avionics, and regulatory evaluation to determine the causes and contributing circumstances associated with aviation occurrences [6]. The primary objective of every investigation focuses on preventing future accidents through the identification of safety deficiencies rather than determining legal responsibility or assigning blame. This philosophy has become a fundamental principle of international aviation safety because comprehensive investigations generate evidence-based recommendations capable of improving aircraft design, maintenance procedures, operational standards, pilot training, airport infrastructure, and regulatory oversight [7]. Investigation activities involve systematic collection and preservation of physical evidence, detailed examination of aircraft structures and components, analysis of flight recorder information, evaluation of maintenance documentation, reconstruction of flight trajectories, assessment of environmental conditions, and comprehensive review of organizational practices. Every stage of the investigation requires close collaboration among specialists representing multiple technical disciplines to ensure accurate interpretation of available evidence [8]. Scientific methodologies, laboratory examinations, computational simulations, digital reconstruction techniques, and engineering analyses collectively support the development of reliable conclusions concerning accident causation [9]. The multidisciplinary nature of aircraft accident investigation reflects the increasing complexity of modern aviation systems, where mechanical reliability,

software functionality, human performance, operational procedures, and regulatory compliance interact continuously throughout every phase of flight. Such comprehensive investigative practices contribute directly to long-term improvements in aviation safety by transforming accident evidence into practical engineering knowledge and effective preventive measures [10].