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CRM strategies for emergency management during single-engine operations in conventional twin-engine aircraft up to 5,700 kg

Abstract

Single-engine operations in conventional twin-engine aircraft represent a critical flight condition, in which the loss of one engine requires rapid decision-making by the pilot and corporate, efficient resource management, and precise aircraft control. In this context, Corporate Resource Management (CRM) becomes an essential tool to improve human performance and reduce the risks associated with human error during emergencies. This study aimed to analyze the applicability and effectiveness of CRM strategies in emergency management during single-engine operations, with a focus on conventional twin-engine aircraft weighing up to 5,700 kg. To this end, a qualitative and descriptive methodological approach was adopted, combining bibliographic and documentary research. Data collection was carried out through a literature review, analysis of operational manuals—namely the Pilot's Operating Handbook (POH) and the Airplane Flight Manual (AFM)—and the study of accident and incident reports provided by the Brazilian Center for Investigation and Prevention of Aeronautical Accidents (CENIPA). Data analysis was conducted through thematic categorization of the collected reports and comparison between officially recommended procedures and the actual practices reported by aviation professionals. As a result, gaps were identified in the application of CRM in these scenarios, and technical recommendations were proposed to improve training programs and operational procedures, thereby contributing to enhanced operational safety.

Keywords: flight safety, human factors, emergency procedures

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Introduction

Civil aviation is essential for global mobility,[1] but it demands a high standard of operational safety, especially in critical situations such as engine failures in twin-engine aircraft. This work focuses on single-engine operations, that is, when one of the engines fails, in small and medium-sized twin-engine aircraft with a maximum weight of up to 5,700 kg, regulated by Brazilian Civil Aviation Regulation No. 91,[2] common in general aviation.

Corporate Resource Management (CRM), which encompasses various practices related to human behavior in the cockpit, has become indispensable in accident prevention. Although widely applied in airlines governed by RBAC 121 and in air taxi and large aircraft companies in executive aviation governed by RBAC 135, its use in operations governed by RBAC 91 still lacks greater application and standardization.

The overall objective is to analyze the human, technical, and environmental factors that contribute to accidents in single-engine operations of twin-engine aircraft, evaluating the applicability and effectiveness of CRM (Corporate Resource Management) training as a risk mitigation strategy in these emergency operations.

To achieve this objective, the following specific goals were defined:

A. To identify the main human factors that contribute to accidents in single-engine operations of twin-engine aircraft, evaluating how technical and environmental elements affect crew decisions and performance;

B. To point out cases of accidents/incidents registered by CENIPA (Center for Investigation and Prevention of Aeronautical Accidents), related to single-engine operations and the lack of CRM (Corporate Resource Management) in the cockpit; and

C. To evaluate the applicability of CRM training in this emergency context and verify how its effectiveness can be increased as standardization is adopted.

The study is based on three pillars: human factors, CRM training, and Safety Management Systems (SMS). Through a critical analysis of current protocols, it sought to propose improvements that increase the resilience of operations and contribute to the reduction of incidents and accidents in this segment of aviation.

Theoretical framework

The theoretical framework was essential for the research, supporting concepts and practices in the analysis of emergency procedures and CRM (Corporate Resource Management) after single-engine operations in twin-engine aircraft. This chapter includes four main topics: Aviation Emergency Procedures, Human Factors, CRM, and SMS (Safety Management System).

Emergency procedures in aviation

Emergency procedures are fundamental to ensuring the safety of passengers and crew during adverse events, such as engine failures. According to... NASA,[3] standardization These procedures are essential to minimize human error and optimize response in critical situations, and although these situations rarely result in accidents, they frequently highlight gaps in crew procedures, training, and coordination, reducing the safety margin. Furthermore, in general aviation, especially in prolonged single-engine operations, pilot preparedness to deal with engine failures is crucial, considering the inherent risks of this type of operation.

Single-engine operations in twin-engine aircraft

Single-engine operations in conventional twin-engine aircraft weighing up to 5,700 kg represent one of the most critical conditions in general aviation. Engine failure causes power asymmetry, resulting in yaw, roll, and significant loss of aircraft performanc,[4] as shown in Figure 1, taken from one of the FAA's publications on multi-engine flight:

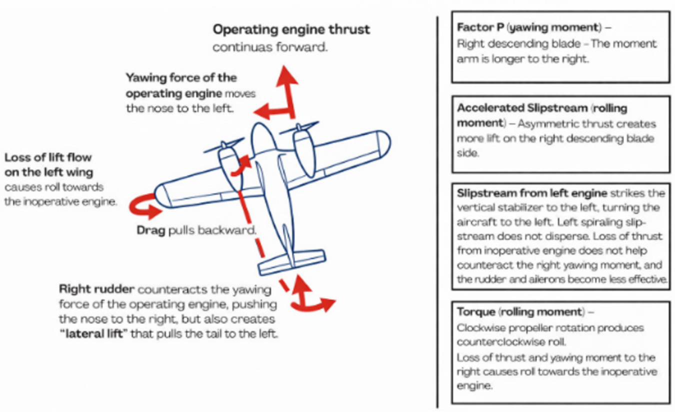

Figure 1 Aerodynamic results of critical engine failure.[4]

In these situations, concepts such as Minimum Controlled Airspeed (MCA), Aircraft Weight and Balance, and aerodynamic configuration come into play to determine successful flight maintenance. The loss of climb rate performance is also significant, as in many light twin-engine aircraft, particularly under conditions of high weight, low atmospheric density, restrictive terrain, and/or high temperature, single-engine performance does not allow for straight and level flight (Middle Georgia State University, 2025). Therefore, for a pilot, it is essential to master immediate actions that include correctly identifying the faulty engine, adopting the "Identify, Confirm, and Correct" principle, feathering the propeller, and strictly adhering to the emergency checklist.[5] The power mismatch combined with the element of surprise demands not only technical skill but also efficient crew coordination, at which point CRM strategies become crucial.[6]

Human factors

According to Wiegmann and Shappell.,[7,8] and Majić.,[9] human error contributes to more than 80% of aviation accidents. In engine failure emergencies, the main critical variables are:

a) Heavy cognitive load: the pilot must receive and process technical information, make quick decisions, and execute maneuvers in constant danger of risking their life and the lives of all passengers.[10]

b) Surprise and shock: the initial shock response impairs decision-making for a few seconds, which can be essential for a successful recovery (Sheffield et al., 2025).

c) Stress and fatigue: decrease situational awareness and can result in errors of perception or performance.[11]

d) Communication failures: Communication between captain and co-pilot can be marked by failures or overlapping speech, generating despair inside the cockpit.[10]

In the Brazilian context, we can cite the Final Report on the accident involving aircraft PT-VCI (Model NE-821 Carajá). This accident also highlighted elements affecting decision-making and coordination of actions in the cockpit during the landing procedure, demonstrating how inadequate case management can impact the outcome of the incident (CENIPA, 2019). The company had previously introduced CRM training, but these initiatives had failed to modify the behavior of experienced captains, highlighting an organization resistant to change. This lack was directly reflected in the cockpit, with a captain who took on all functions, disregarded the advice of his co-pilot, and performed an improvised instrument flight rules (IFR) procedure. In this context, CENIPA concluded that, although CRM was formally implemented in the company, it was not effectively practiced, which compromised the coordination, communication, and decision-making of the crew, which were determining factors in the loss of control of the aircraft.

In practice, these human factors can result in errors, such as shutting down the wrong engine (the one that remains running), delays in correctly executing the emergency checklist, or losing control of the aircraft at low speed. Understanding these issues is fundamental for CRM training in small aircraft.[12]

Crew resource management (CRM)

Crew Resource Management (CRM) was developed in response to major accidents in the 1970s, which highlighted that technology alone was not sufficient to prevent catastrophic failures. For example, the Tenerife disaster (1977) underscored the need for unambiguous, assertive, and non-hierarchical communication between cabin crews and air traffic controllers (McAndrew, 2014; NTSB, 1986).

The pillars of CRM are:

A. Communication – a reciprocal exchange that must be objective, clear, and free from ambiguity.[13]

B. Leadership – the commander as a manager of resources and not just an executor of limited tasks (Helmreich et al., 1999).

C. Situational awareness - awareness of the operational context and environmental variables surrounding the flight.[14]

D. Decision-making – structured processes to eliminate cognitive biases under pressure, especially during emergency situations.[15]

E. Work distribution - tasks well distributed among the teams, highlighting the priority and critical ones.[16]

According to the figure below, CRM can be understood as a combination of knowledge and skills to improve operational safety by optimizing two types of resources: human and technical. The diagram in Figure 2 shows that teamwork, workload management, and adaptability competencies, as well as communication, professionalism, efficiency, and reflective performance competencies, are interconnected.

Applying these elements in a synchronized manner minimizes the risk of failures due to cognitive biases, mental workload, or poor communication.[13,17]

Although widely used in commercial operations under RBAC 121 and 135, based on the literature we can say that CRM is still underutilized in light aircraft operated under RBAC 91. Many private pilots and operators do not receive specific CRM training, which increases vulnerability to single-engine emergencies.[16,18]

SMS and RBAC 91

The Safety Management System (SMS), as defined by ICAO in Annex 19[19] and detailed in Doc 9859 – Safety Management Manual,[20] consists of a systematic framework of policies, processes, and practices to identify hazards and, together with this, assess and control risks. The SMS has been included in several Brazilian regulations adopted by ANAC based on international guidelines describing its application to scheduled airlines and air taxi services (ANAC, 2016a; ANAC, 2016b). According to Figure 3 shown below, we can observe the main objectives of the SMS:

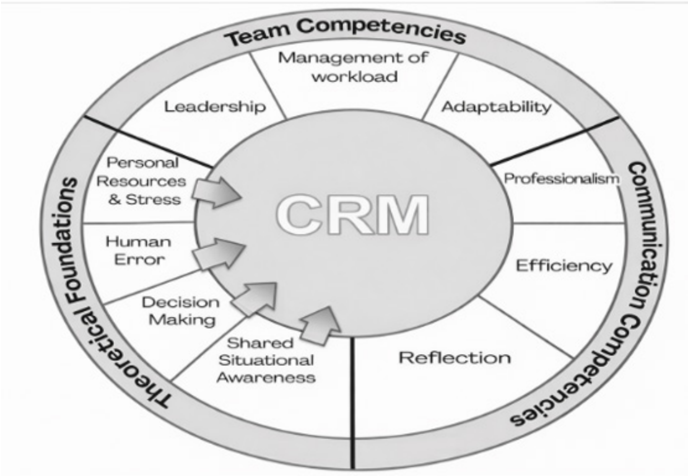

Figure 2 Essential elements of crew resource management (CRM).

Figure 3 Roles and responsibilities within the SMS.

Although its operation is not mandatory for general aviation, governed by RBAC 91, its adapted application in private operations can bring significant safety gains (ANAC, 2024). For example:

1) Collection and analysis of flight data.[20]

2) Preventive and corrective maintenance reports (Rocha, 2023).

3) Accident/incident report.

4) Internal CRM programs, even in companies with only one or two airplanes.[21]

The SMS (Safety Management System) therefore functions as a complement to the CRM (Crew Resource Management) system, where CRM operates in the cockpit, the SMS ensures feedback within organizations and creates an organizational culture that values prevention and continuous learning for all who contribute to greater flight safety (ANAC, 2019).[21]

Additionally, it is pointed out that the integration between risk management, SMS (Safety Management System), and operational sustainability offers not only solid safety in aviation but also organizational resilience in complex conditions, such as those experienced by private operators under RBAC 91.[22] Thus, even in the absence or direct imposition through regulations, the voluntary implementation of SMS elements by executive aviation companies will serve as a differentiator, as it will build greater trust with clients and operational predictability, in addition to contributing to the necessary adjustment in general aviation in order to align with the standards of excellence of major international operators.[23,24]

Work methodology

This study aimed to analyze the applicability of CRM strategies in emergency management during single-engine operations in conventional twin-engine aircraft, focusing on aircraft up to 5,700 tons.kg. To this end, a literature review was conducted on the concepts and guidelines of this mitigating tool, and an analysis of air accident reports involving single-engine aircraft failures was carried out.A comparative evaluation of training procedures and practices applied to small-scale executive aviation.According to Gil (2009), bibliographic research is developed from material already published and academically validated by professionals in the field, and is necessary to theoretically ground the study and identify gaps in the literature written by the author.

Type and approach of the research

This research was characterized as qualitative and descriptive, seeking to interpret and understand phenomena and behaviors related to the use of CRM techniques in engine failure situations in conventional twin-engine aircraft weighing up to 5,700 kg. The qualitative method allows for an interpretive analysis of the human and operational reality of general aviation, while descriptive analysis, according to Gil (2009), allows for a description and understanding of pilots' practices and attitudes in emergency situations without direct influence on the events.

Methodological procedures

Data collection was carried out through searches in academic databases such as SciELO, CAPES Journals, and Google Scholar, as well as official technical documents from ANAC, CENIPA, ICAO, FAA, and EASA. This approach aligned with what Marconi and Lakatos (2003) define as a bibliographic information source, in which the aim is to identify and analyze already published materials to support the investigation. The descriptors used included terms such as "Crew Resource Management," "Single-engine emergency," and "Single-engine operation."

Because this is a qualitative study, the conclusions cannot be generalized to the entire universe of general aviation. The focus is on a specific segment of the sector, encompassing single-engine operations in conventional twin-engine aircraft up to 5,700 kg, under RBAC 91 and restricted to Brazilian territory. Furthermore, there is little detail in some CENIPA reports regarding the human behavior of the crew during the events, which limits the knowledge about the application of CRM. However, the triangulation between literature, official statistics, and operational practice is sufficient to understand the phenomenon and suggests improvement strategies aimed at executive aviation and instruction under RBAC 91.

Inclusion criteria

The first stage of this project included a thorough literature review to provide a solid theoretical basis for the fundamentals of CRM and its applications in single-engine emergency situations in twin-engine aircraft weighing up to 5,700 kg. The information was obtained from valid national and international sources in the academic field, such as technical operations manuals, scientific articles, official reports, and aeronautical regulations.

Materials published between 2000 and 2024 in Portuguese, English, French, and Spanish that directly addressed the central theme or related topics, such as operational safety, cockpit resource management, and human behavior in aviation emergencies, were prioritized.

Following Prodanov and Freitas (2013, p. 129), the choice of a body of literature adhered to criteria of clarity, relevance, and agreement with the research objectives, ensuring coherence between units and up-to-date references. Sources with undetermined authorship or questionable content were eliminated to ensure the scientific legitimacy of the research. The analysis of the obtained material followed a qualitative approach, of a categorical nature (Marconi; Lakatos, 2002), that is, a process of selection, coding, and contrast of all the data obtained. The theoretical contents were compared with procedures and official standards of aeronautical manuals and regulations, in search of convergences, divergences, and content gaps.

Document analysis

The second stage of the study was based on a documentary analysis of aeronautical accident and incident reports made available by the Center for Investigation and Prevention of Aeronautical Accidents (CENIPA). This analysis allowed for the examination of real events, contributing to the understanding of the operational and human factors associated with the investigated occurrences.

The research covered the years 2007, 2009, 2010, 2012, 2014, 2015, and 2017, encompassing approximately a decade of records related to engine failures in twin-engine light aircraft, such as the Piper Seneca, Embraer Carajá, Cessna 402, and Piper PA-31 Navajo. All aircraft analyzed had a maximum takeoff weight equal to or less than 5,700 kg, in accordance with the scope defined for the study.

The criteria for selecting the reports included: incidents involving partial or total engine failure; operations conducted under RBAC 91 or RBAC 135 regulations, excluding military and experimental operations; and complete final reports containing factual information, identification of the probable cause, and operational safety recommendations. These criteria ensured methodological consistency and the relevance of the data analyzed.

Each report was considered along three main lines:

a) Technical aspects: type of technical failure, altitude, flight phase, weather conditions;

b) Human aspects: communication between crew members, leadership, stress, decision-making, and the application of checklists;

c) Organizational aspects: prior training, standardization of procedures, and operator safety attitude.

This analysis made it possible to identify the differences and gaps between CRM theory and performance in real emergency situations.

Thematic categorization

The third stage was a thematic synthesis, using a qualitative technique to categorize the evidence, highlighting themes and patterns based on predefined conceptual categories. Four analytical categories were created: Human Factors, Emergency Management, Decision Making, and CRM Application.

The categorization was conducted comparatively, contrasting data from CENIPA reports with recommended practices in training manuals and POH/AFM (Pilot's Operating Handbook / Aircraft Flight Manual) for the aircraft studied. Finally, the results were compiled into an interpretive framework associating the observed human factors with the presence or absence of CRM practices, facilitating the identification of common failures and suggesting mitigation recommendations.

Study selection process

The material selection process was conducted in four sequential stages, ensuring the relevance, timeliness, and applicability of the sources to the proposed theme, as shown in Table 1.

Table 1 Step-by-step study selection process

Step	What?	Result
First	Initial search	Identification of 112 documents in the CENIPA, SciELO, FAA Library, Google Scholar and ICAO Publications databases, using the descriptors: "Crew Resource Management", "CRM in general aviation", "engine failure", "single-engine operation", "human factors", "decision making under stress" and "twin-engine aircraft below 5700 kg". Also included were 8 (eight) official accident reports from CENIPA (PT-ENM, PT-VCI, PT-WIG, PT-OCV, PT-LHE, PT-WEH, D-GOMM, PR-FLM).
Second	Screening by title and abstract	79 documents were excluded because they did not meet the inclusion criteria, due to: Focus on commercial or military aviation; Lack of relevance to CRM or human factors; Approach restricted to technical aspects without behavioral content. 33 pre-selected documents remained, in addition to the official reports.
Third	Full review	A comprehensive analysis of the 33 documents and reports was conducted. 18 studies were excluded due to superficial research or a lack of data applicable to general aviation. 15 core documents remained, including the 8 CENIPA reports and 7 scientific and regulatory publications (ICAO, FAA, ANAC, Dekker, Wiegmann and Shappell, Salas et al, Idowu et al).
End	Result	The final corpus of the research consisted of 15 main references, organized into three complementary groups: **a)** 8 official accident reports.[25–28] **b)** 4 theoretical and scientific studies on human factors and CRM. **c)** 3 international and national normative manuals and publications.

Thus, the material selection process was conducted in a systematic, rigorous, and progressive manner, ensuring that the final research corpus included only relevant, up-to-date sources directly aligned with the study's objectives. The combination of official aircraft accident reports, theoretical studies on human factors and CRM, as well as manuals and normative publications, enabled an integrated approach between theory and practice, strengthening the analysis of single-engine operations in twin-engine aircraft from an operational safety perspective.

Selected documents

After carrying out the step-by-step selection process outlined in Table 1, it was possible to list the selected documents, as shown in Table 2.

Table 2 Selected documents

Classification of document	Reference / Author	Subject
Technical Reports (CENIPA)	CENIPA[25–28] – Official accident reports involving aircraft PT-ENM,[29] PT-VCI,[30] PT-WIG,[27] PT-OCV,[31] PT-LHE,[32] PT-WEH,[26] D-GOMM[28] and PR-FLM[25]	A series of investigations into engine failures in twin-engine aircraft weighing ≤ 5,700 kg, highlighting deficiencies in CRM (communication, leadership, coordination, judgment, and checklist execution). These investigations served as a basis for identifying patterns of human error, non-standardized decision-making, and the impact of the absence of CRM in the emergencies analyzed.
International Normative Manual	ICAO[20] – Doc 9683 – Human Factors Training Manual	ICAO guidelines for training in human factors and CRM, addressing communication, leadership, and cabin resource management.
International Normative Manual	FAA (2020) – Human Factors Guide for Aviation Maintenance and Flight Operations	The "Fly, Navigate, and Communicate" model and CRM principles geared towards general and executive aviation, applied to the interpretation of CENIPA cases.
National Regulatory Manual	ANAC (2022) – IS 120-003A – CRM Training	Brazilian standards for CRM training standardization in RBAC 91, 121 and 135; basis for the recommendations proposed in the discussion.
Central Scientific	DEKKER S.,[33] – The Field Guide to Human Error Investigation	Conceptual foundation regarding human error and behavior in critical failure situations, used for interpreting the human factors identified in the analyzed cases.
Central Scientific	WIEGMANN DA; SHAPPELL SA[7,8] – A Human Error Analysis of Commercial Aviation Accidents using the HFACS	It presents the HFACS (Human Factors Analysis and Classification System) model, which identifies human and organizational failures as contributing factors in aircraft accidents. It is used to categorize the human factors found in CENIPA reports.
Central Scientific	SALAS, E. et al.,[13]– Does Crew Resource Management Training Work?	Empirical review on the effectiveness of CRM in crew performance, demonstrating the reduction of cognitive and behavioral errors after structured training. This served as the basis for evaluating the effectiveness of CRM discussed in Section 4.
Central Scientific	IDOWU, A. et al.,[12] – Evaluating Crew Resource Management (CRM) and its Effectiveness.	A contemporary study on the effectiveness and performance indicators of CRM in general and executive aviation. Used to discuss the applicability of CRM under RBAC 91 and to propose practical training recommendations.

After consolidating the documents presented in Table 2, it is observed that the set of selected sources offers a consistent theoretical, normative, and empirical basis for the proposed analysis. The articulation between technical reports from the Aeronautical Accident Investigation and Prevention Center, national and international normative manuals, and central scientific studies on human factors and CRM enabled an integrated approach between practical evidence and conceptual frameworks.

Results and discussion

This section presents the analysis and discussion of the results obtained from the literature review of selected documents, addressing contributing factors to accidents in single-engine aircraft operations, analysis of accidents and incidents from CENIPA (Center for Investigation and Prevention of Aeronautical Accidents) and CRM (Center for Risk Management) as a mitigation strategy.

Predominant human factors

Analysis of the reports revealed that human factors were the most recurring and critical elements in the accidents. Inadequate decision-making under stress, lack of effective communication, loss of situational awareness, and weak leadership in the cockpit were present in 7 of the 8 incidents analyzed.

These results align with the HFACS model, originally presented by Wiegmann and Shappell.,[7,8] where human errors were viewed as products of systemic and supervisory failures, rather than based solely on individual failures. Among the cases analyzed, behaviors such as hesitation, impulsivity, and lack of cross-checking of checklists were associated with the absence of formal CRM training.

Furthermore, according to Salas et al.,[13] the effectiveness of CRM is entirely linked to the crew's ability to communicate openly, manage situational awareness, and manage workload effectively.

Interaction between technical factors and crew decisions

Single-engine operations in twin-engine aircraft impose a high cognitive and technical load environment. At the same time, the pilot has to monitor items such as thrust asymmetry, vibration, performance limitations, and system management items that require quick and precise decisions. However, as Dekker[33] and ICAO[20] state, such human behavior cannot be dissociated from its technical aspect in a critical situation, since the machine influences the mind and vice versa.

Cockpit ergonomics, instrument organization, and the quality of visual or audible signals further disrupt the perception of information, which therefore negatively influences decision-making. An inaccurate instrument panel or a vague interpretation of the warning system can make such an error possible, even if the pilots have done everything they were instructed to do. This pattern is driven by the theory of "systemic error," where failures result from an imperfect interaction between man, machine, and environment.[33]

The FAA (2020) also emphasizes the importance of being able to make accurate decisions in the face of technical limitations, in accordance with the simultaneous application of CRM, with the principles of "Fly, Navigate and Communicate," that is, prioritizing aircraft control over communication and navigation. The success of a single-engine operation, therefore, requires more than technical ability; it demands cognitive coordination and efficient use of limited resources.

Environmental factors and operational impact

The operational environment acts as a complexity multiplier. The psychological and physical workload of the crew increases due to adverse weather conditions, night flight operations with reduced visibility, and complex terrain.

According to Salas et al.,[13] prolonged exposure to negative environments decreases the capacity for logical reasoning, and Idowu et al.,[12] observe that the absence of situational adaptation will lead to an increased possibility of errors in judgment and communication.

ICAO[20] highlights that environmental factors impact human performance at all levels, whether perceptual, cerebral or motor, and these aspects need to be incorporated into CRM training. Environmental mastery, therefore, encompasses not only piloting skills, but also the anticipation of threats, contingency planning, and mutual situational awareness—essential fundamentals for mitigating risks in a single-engine emergency.

Thus, we can conclude that it is an interaction of human, technical, and environmental aspects—the three pillars of safety in operations. When not properly governed, they will result in decision fatigue and operational errors. Through CRM culture and SMS (Safety Management System), they systematically become powerful shields against accidents.

Analysis of accidents and incidents: characterization of samples

Eight official reports from CENIPA (Center for Investigation and Prevention of Aeronautical Accidents) were analyzed, confirming the studied data, occurring between the years 2007, 2009, 2010, 2012, 2014, 2015, and 2017. These occurrences represent emblematic cases in which engine failures resulted in fatal or serious accidents, frequently associated with CRM (Central Mechanical Reduction) deficiencies.

Table 3 below summarizes the information collected and relates the human factors and CRM practices observed in each event analyzed:

Table 3 Correlation between human factors and CRM practices observed in engine failure incidents (2007 – 2017)

These patterns indicate that the Human Factor was the main cause of what occurred and that issues related to human error due to a negligent CRM training regime were common in the vast majority of these incidents/accidents, consistent with the findings of Salas et al. (2001) and Idowu et al. (2024), whose results also indicate a lower rate of cognitive failures and higher quality emergency responses when CRM is part of an ongoing training program.

Applicability of CRM in single-engine operations

CRM is most relevant precisely during critical failures and stressful situations, when complex coordination and communication are necessary. The data analyzed indicate that, without these skills, even the most experienced pilots lose their judgment. According to ICAO[20] and FAA (2020), CRM training programs should emphasize five key competencies: communication, leadership, situational awareness, teamwork, and decision-making.

Effectiveness and standardization of training

According to Idowu et al.,[12] the effectiveness of CRM depends on its integration with the Safety Management System (SMS) and its standardization among operators. The article showed that operations under RBAC 91 lack this standardization and highlighted the lack of consistency in training.

To improve CRM effectiveness, it is recommended that this training be made mandatory in conjunction with ongoing training programs, as proposed by ANAC IS 120-003A (2022), which until now only applies to RBAC 121, considering realistic engine failure exercises associated with decision-making under pressure.

Practical recommendations

Based on the findings of this study, it is proposed that business aviation operators, under RBAC 91, adopt the following measures:

A. Annual CRM training with emphasis on single-motor failures;

B. Practical simulations integrated into technical training;

*C. Briefings*Standardized requirements for flight instruction;

D. Integrating CRM with SMS as a preventative tool;

E. Monitoring effectiveness through post-training reports and internal audits.

These practices align with the modern view of operational safety advocated by Salas et al. (2001) and Dekker (2007), who state that safety emerges from the control of human behavior and not just from mastery of technique.

Integrative summary of results

The results presented prove that:

a) Human factors are the main contributors to accidents in single-engine aircraft operations;

b) The absence or deficiency of CRM (Customer Relationship Management) increases the potential for errors in judgment and communication.

c) To improve operational safety under RBAC 91, standardization and formal training regarding CRM are mandatory.

According to the HFACS[7,8] and Dekker[33] models, human error is not a cause, but a consequence of the interaction between the individual, the environment, and the organization. Thus, CRM is consolidated as the link between human behavior and safe operational performance.[34–63]

Final consideration

An analysis of eight official reports on air accidents, investigated by CENIPA, that occurred between 2007 and 2017, involving conventional twin-engine aircraft weighing less than 5,700 kg, indicated human factors and inconsistent application of CRM (Crew Resource Management) as determining factors in most accidents. In 7 out of 8 cases, important components failed to function as expected. Communication, situational awareness, teamwork in the cockpit, and the ability to make clear decisions under pressure demonstrated that possessing technical skills was not sufficient to guarantee safe flight during a single-engine emergency.

The lack of standardized briefings, absence of cross-supervision between pilot in command and co-pilot, and the failure to strictly adhere to checklists were consistent findings, especially in operations conducted under degraded weather conditions, during training flights, or under company pressure. These behaviors highlighted the specific influence of cultural and psychosocial factors on operational safety, corroborating the empirical findings identified in the analyzed reports.

Another interesting finding concerns CRM training, as well as its standardization, in small air taxi companies and aviation schools, especially in programs that neglect the integration between theoretical content and practice in aircraft of the same operational type. This disconnect causes a negative transfer of learning, resulting in an inability to respond effectively to real emergencies.

The study suggests that the scope of CRM effectiveness should extend far beyond regulatory compliance, as it consolidates itself as a pillar of risk management and the development of an organizational culture focused on safety. Building a just culture, promoting assertive communication at all levels, and continuously reviewing training programs are essential to minimize human error and prevent the recurrence of critical patterns observed in such cases.

Therefore, it can be concluded that, under these conditions, an organization's maturity in operational safety depends on its success in internalizing CRM principles not as a skill, but as a collective attitude. The integration of technical competence, resource management, and human behavior is the most effective way to transform CRM into a preventive and lasting instrument, capable of reducing the accident rate and raising the standard of Brazilian executive and general aviation.

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Conflicts of interest

The author declares that there are no conflicts of interest.

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