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Extending HFACS Beyond the Organizational Boundary: A State Safety Governance and Oversight Analysis of the VoePass Flight 2283 Accident

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This study examines the VoePass Flight 2283 accident using the Human Factors Analysis and Classification System (HFACS) and proposes State Safety Governance and Oversight (SSGO) as a fifth analytical level to examine how operational, supervisory, organizational, and State-level conditions collectively influenced the accident. A qualitative case study using directed content analysis was conducted based primarily on evidence documented in the CENIPA final investigation report. Contributing factors were independently coded and classified through consensus across the four traditional HFACS levels and the proposed SSGO level, comprising five categories: State safety governance and regulatory framework, state safety capability and resources, certification and regulatory control, safety surveillance, safety intelligence, and risk management, and safety intervention and Resolution. The analysis identified unsafe acts associated with icing operations, aircraft-performance management, and procedural execution, together with supervisory and organizational deficiencies involving maintenance control, safety culture, discrepancy reporting, training, operational risk management, and Safety Management System implementation. The proposed SSGO level identified State-level influences related to surveillance, regulatory intervention, and the sustained resolution of known safety deficiencies. Overall, the findings indicate that the accident is best understood as the outcome of interacting system-level conditions rather than isolated frontline errors. This study extends HFACS by introducing State Safety Governance and Oversight (SSGO) as a fifth analytical level, providing a structured approach for examining how State safety oversight may shape organizational safety performance without assuming direct causality. The proposed framework offers a foundation for future applications and empirical validation across aviation accidents and regulatory systems.

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Introduction

Commercial aviation is widely recognized as one of the safest modes of transportation, reflecting decades of advances in aircraft design, operational procedures, regulatory oversight, and safety management systems (International Air Transport Association, 2026; Berezovski, 2026). Despite these achievements, accidents continue to occur, often resulting from complex interactions among technical, human, organizational, and environmental factors rather than a single initiating event. Contemporary accident investigation therefore embraces a systems perspective, recognizing that unsafe acts committed by frontline operators frequently represent the final manifestation of latent conditions embedded throughout the broader aviation system (Reason, 1998). This shift from assigning blame to understanding systemic interactions has fundamentally transformed aviation safety over the past three decades and continues to guide accident investigation and prevention efforts (International Civil Aviation Organization [ICAO], 2018).

Reason's organizational model of accident causation provided the theoretical foundation for this systems perspective by proposing that accidents emerge from the alignment of active failures and latent organizational conditions (1997). Rather than viewing pilot error as the primary cause of accidents, the model argues that unsafe acts are often enabled or promoted by deficiencies originating within higher organizational levels. Building upon this theoretical framework, Shappell and Wiegmann (2000) developed the Human Factors Analysis and Classification System (HFACS), which operationalized Reason's model (1997, 1998) into four interconnected levels: Unsafe Acts, Preconditions for Unsafe Acts, Unsafe Supervision, and Organizational Influences. HFACS enables investigators to systematically identify both active failures and latent conditions, thereby supporting more comprehensive analyses and the development of targeted safety interventions (Li & Harris, 2006; Mendonca et al., 2017; Meng & Lu, 2022; Small, 2020).

Since its introduction, HFACS has become one of the most widely applied human factors frameworks in aviation safety research and accident investigation. The framework has been employed to analyze military, commercial, and general aviation accidents, demonstrating strong inter-rater reliability and providing empirical support for the relationships among organizational influences, supervisory practices, preconditions, and unsafe acts (Li & Harris, 2006; Patterson & Shappell, 2010; Tvaryanas et al., 2006). Subsequent studies provided empirical support for Reason’s (1997) hierarchical model by identifying statistically significant pathways linking higher-level organizational deficiencies with unsafe supervision, adverse preconditions, and ultimately operator errors (Li & Harris, 2006; Li et al., 2008; Yang & Mott, 2021). Beyond aviation, HFACS has also been applied and adapted in maintenance, air traffic control, rail transportation, mining, healthcare, and other high-risk industries, illustrating both its robustness and its flexibility across operational domains (Diller et al., 2014; Krulak, 2006; Reinach & Vialle, 2006; Patterson & Shappell, 2010; Scarborough et al., 2005).

Although HFACS has substantially advanced the understanding of human and organizational factors in accidents, the original framework was primarily designed to examine influences within the operating organization (Shappell et al., 2007). Consequently, factors originating outside the operator, including State-level influences associated with aviation legislation and regulations, certification and approval, safety oversight, surveillance, enforcement, and the resolution of safety issues, are not explicitly represented within the original four-level hierarchy. In modern commercial aviation, however, safety performance depends not only on airline management but also on the effectiveness of the State's safety governance, management, and oversight system. State responsibilities extend across multiple components of civil aviation, including air operators, aircraft airworthiness, maintenance organizations, personnel licensing, aerodromes, and air navigation services, as well as the implementation of State Safety Program (SSP) principles (ICAO, 2018, 2025a). These State-level governance and oversight functions may shape organizational practices long before unsafe supervisory actions or operational errors become evident. Yet, their role is often addressed only indirectly within traditional HFACS analyses.

Previous research provides precedent for extending HFACS beyond its original structure to address influences specific to different operational domains. Reinach and Viale (2006) adapted HFACS for railroad operations, developing HFACS-RR, which added a fifth “Outside Factors” level comprising Regulatory Oversight and the economic, political, social, and legal environments. Building on this approach, Patterson and Shappell (2010) developed the Human Factors Analysis and Classification System-Mining Industry (HFACS-MI), incorporating an additional level termed “Outside Factors” to account for external influences such as government regulations, inspections, enforcement activities, and public policy. These adaptations demonstrate that HFACS can accommodate systemic influences beyond the operating organization when supported by theoretical and operational justification. However, these extensions were developed for the railroad and mining domains, respectively, and do not provide a functionally differentiated framework specifically addressing the State safety governance, management, and oversight functions characteristic of international civil aviation..

On August 09, 2024, an ATR 72-500 operated by VoePass Linhas Aéreas as Flight 2283 crashed near Vinhedo, São Paulo, Brazil, while operating a scheduled passenger flight from Cascavel, Paraná, to Guarulhos, São Paulo, resulting in the loss of all 62 occupants. The aircraft encountered severe icing conditions during the en-route phase and subsequently experienced a loss of control, entering an abnormal flight condition from which recovery was not achieved before ground impact. The investigation examined a complex combination of operational, technical, human, organizational, and regulatory circumstances surrounding the accident. The final investigation conducted by the Brazilian Aeronautical Accident Investigation and Prevention Center (CENIPA) identified numerous human, organizational, operational, and technical factors that contributed to the accident (CENIPA, 2026). While many of these findings can be classified within the traditional HFACS structure (Shappell & Wiegmann, 2000), several relate to State-level functions extending beyond the organizational boundary represented by the original framework.

Building upon the systems logic of HFACS, previous adaptations that extended the framework to external and regulatory influences (e.g., Reinach & Viale, 2006; Patterson & Shappell, 2010), and established ICAO (2018, 2025a, 2025b) principles for State safety oversight and safety management, this study proposes the Human Factors Analysis and Classification System-State Safety Governance and Oversight (HFACS-SSGO). Developed specifically for civil aviation, HFACS-SSGO retains the four original HFACS levels while introducing State Safety Governance and Oversight (SSGO) as a fifth analytical level dedicated to the systematic examination of State-level influences. Unlike previous Outside Factors extensions, in which regulatory influences constitute one component of a broader external-factors level (e.g., Reinach & Viale, 2006; Patterson & Shappell, 2010), SSGO focuses specifically on State safety governance and oversight and differentiates the legal, regulatory, institutional, resource, certification, surveillance, safety risk management, and intervention functions through which a State governs, manages, and oversees the safety of its civil aviation system (ICAO, 2018, 2025a, 2025b). To the author's knowledge, no previous HFACS adaptation has proposed a dedicated analytical level specifically designed to examine State safety governance and oversight functions within the context of civil aviation accident investigation. The proposed framework is initially applied to the VoePass accident (CENIPA, 2026) to examine its utility for identifying and integrating State-level latent conditions within the broader HFACS hierarchy. The official investigation conducted by CENIPA documented a complex interaction of operational, technical, human, supervisory, and organizational factors contributing to the accident, while also identifying evidence relevant to the examination of broader State safety governance and oversight functions (CENIPA, 2026). Although many of these findings can be classified within the traditional HFACS structure (Shappell & Wiegmann, 2000), several relate to State safety governance and oversight functions that extend beyond the analytical scope of the original four-level framework. Building upon the systems logic of HFACS, previous adaptations that extended the framework to external and regulatory influences (e.g., Reinach & Viale, 2006; Patterson & Shappell, 2010), and established ICAO (2018, 2025a, 2025b) principles for State safety oversight and safety management, this study proposes the HFACS-SSGO. Developed specifically for civil aviation, HFACS-SSGO retains the four original HFACS levels while introducing SSGO as a fifth analytical level dedicated to the systematic examination of State-level influences. Unlike previous Outside Factors extensions, in which regulatory influences constitute one component of a broader external-factors level, SSGO focuses specifically on State safety governance and oversight and differentiates the legal, regulatory, institutional, resource, certification, surveillance, safety risk management, and intervention functions through which a State governs, manages, and oversees the safety of its civil aviation system (ICAO, 2018, 2025a, 2025b). To the author's knowledge, no previous HFACS adaptation has proposed a dedicated analytical level specifically designed to examine State safety governance and oversight functions within the context of civil aviation accident investigation. The proposed framework is initially applied to the VoePass Flight 2283 accident to examine its utility for identifying and integrating State-level latent conditions within the broader HFACS hierarchy. Accordingly, this study addresses the following research questions (RQs)::

RQ1: What contributing factors associated with the VoePass Flight 2283 accident can be identified and classified across the four levels of the HFACS framework?

RQ2: What State-level safety governance and oversight factors are evident in the accident context, and how does their incorporation through the proposed SSGO level extend the systemic analysis provided by HFACS?

Methodology

This study employed a qualitative case study design using directed content analysis (Patton, 2015) to examine the contributing factors identified in the final investigation of the VoePass Flight 2283 accident (CENIPA, 2026). The four traditional levels of the HFACS (Shappell et al., 2007; Shappell & Wiegmann, 2000) were applied to classify human and organizational factors documented in the investigation report. In addition, this study proposed and initially applied SSGO as a fifth analytical level to examine latent State conditions extending beyond the operating organization represented by the original HFACS framework. Collectively, the five levels constitute the proposed HFACS-SSGO framework. A case study approach was considered appropriate because it allows an in-depth examination of complex interactions among operational, organizational, and institutional factors within their real-world context (Patton, 2015; Yin, 2018).

Unlike conventional content analysis, which derives categories inductively from the data, directed content analysis begins with an established theoretical framework that guides the initial coding process (Hsieh & Shannon, 2005). Consistent with this approach, the four traditional HFACS levels, Unsafe Acts, Preconditions for Unsafe Acts, Unsafe Supervision, and Organizational Influences served as the initial coding framework for the analysis (Shappell & Wiegmann, 2000). To extend HFACS beyond its traditional organizational boundary, SSGO was developed as a higher-order analytical level encompassing State-level governance and safety oversight functions within civil aviation (ICAO, 2018, 2025a). The development of SSGO was grounded in the systems logic underlying HFACS, informed by previous adaptations that incorporated regulatory influences (Patterson & Shappell, 2010), and supported by established ICAO principles and responsibilities related to State safety oversight, the State Safety Program (SSP), and State safety management. The resulting five-level framework was then applied to the VoePass (CENIPA, 2026) accident to examine both the contributing factors documented by CENIPA and the relationships among State-level, organizational, supervisory, operational, and frontline conditions.

Data Sources

The primary data source was the official final investigation report issued by CENIPA concerning the accident involving VoePass Flight 2283 (Aircraft PS-VPB), which occurred on 9 August 2024 near Vinhedo, São Paulo, Brazil (CENIPA, 2026). The report was selected because it provides the most comprehensive and authoritative account of the accident, including factual information, technical analyses, contributing factors, conclusions, and safety recommendations. The analysis focused on findings supported by evidence documented within the report, particularly those related to flight operations, crew performance, supervision, organizational processes, Safety Management Systems (SMS), certification, surveillance, and regulatory oversight. Additional sources included the original HFACS publications (Shappell & Wiegmann, 2000; Wiegmann & Shappell, 2003; Shappell et al., 2007), subsequent validation and adaptation studies (Li & Harris, 2006; Reinach & Viale, 2006; Tvaryanas et al., 2006; Li et al., 2008; Patterson & Shappell, 2010; Mendonca et al., 2017; Yang & Mott, 2021), and relevant ICAO standards and guidance on aircraft accident investigation, State safety oversight, safety management, and safety intelligence (ICAO, 2018, 2024, 2025a, 2025b). These sources informed the theoretical and operational development of the analytical framework, including the proposed SSGO level. These supplementary sources informed framework development and classification but were not used to identify accident-specific contributing factors beyond those supported by the CENIPA (2026) final report.

Analytical Framework

The accident was analyzed using HFACS-SSGO, an extended five-level framework proposed in this study. The framework retains the four levels of the original HFACS taxonomy proposed by Shappell and Wiegmann (2000), Unsafe Acts, Preconditions for Unsafe Acts, Unsafe Supervision, and Organizational Influences and applies the original HFACS categories and definitions without modification to Levels 1 through 4. SSGO is introduced as a fifth analytical level to capture underlying State conditions associated with governance, safety management, and safety oversight that extend beyond the scope of the conventional HFACS framework. The development of SSGO was informed by previous HFACS adaptations incorporating regulatory influences (Reinach & Viale, 2006; Patterson & Shappell, 2010) and grounded in established ICAO provisions and guidance concerning aircraft accident investigation, State safety oversight, and the State Safety Program (ICAO, 2018, 2024, 2025a, 2025b). These State responsibilities extend across civil aviation, including personnel licensing, aircraft operations, certification and airworthiness, maintenance organizations, aerodromes, and air navigation services.

Rather than directly adopting ICAO's Critical Elements or SSP components (ICAO, 2018) as HFACS categories (Shappell & Wiegmann, 2000), the proposed SSGO taxonomy synthesizes established State safety principles and responsibilities into five categories representing distinct types of State-level latent conditions relevant to accident analysis: (1) State Safety Governance and Regulatory Framework, (2) State Safety Capability and Resources, (3) Certification and Regulatory Control, (4) Safety Surveillance, Safety Intelligence, and Risk Management, and (5) Safety Intervention and Resolution.

This conceptualization is also consistent with ICAO's *Safety Intelligence Manual*, which recognizes that effective State safety management extends beyond the collection of safety data to the generation of actionable safety intelligence supporting risk-informed decision making. The Manual emphasizes that standardized taxonomies, analytical capability, governance arrangements, and adequate organizational resources are fundamental to identifying emerging safety issues, integrating safety information from multiple sources, and supporting timely safety interventions (ICAO, 2025b). These principles further support the proposed SSGO framework by recognizing State-level governance, surveillance, safety intelligence, and intervention as interrelated functions essential to effective safety oversight (see Table 1).

Table 1

Proposed State Safety Governance and Oversight (SSGO) Taxonomy

SSGO Category	Definition
State Safety Governance and Regulatory Framework	Latent conditions associated with the State's aviation safety policies, legislation, regulations, institutional arrangements, assignment of responsibilities, authority, coordination, and overall governance of civil aviation safety.
State Safety Capability and Resources	Latent conditions associated with the adequacy, availability, competence, and allocation of human, financial, technical, and technological resources, and institutional capacity, necessary to fulfill State safety responsibilities commensurate with the size, complexity, and evolution of the civil aviation system.
Certification and Regulatory Control	Latent conditions associated with State licensing, certification, authorization, approval, and other regulatory controls used to establish and maintain the acceptability of persons, organizations, products, systems, and activities within civil aviation.
Safety Surveillance, Safety Intelligence, and Risk Management	Latent conditions associated with the State's ability to monitor compliance and safety performance; collect, integrate, and interpret safety information; identify emerging or systemic hazards; assess safety risk; and determine when State-level safety action is warranted.
Safety Intervention and Resolution	Latent conditions associated with the adequacy, timeliness, proportionality, escalation, follow-up, and effectiveness of State actions taken in response to identified safety deficiencies or unacceptable risks, including corrective measures, restrictions, enforcement, and verification of sustained resolution.

The SSGO categories were defined according to the underlying State safety function rather than the aviation domain or regulated entity involved, allowing the framework to be applied to State-level conditions involving air operators, aircraft and component certification and airworthiness, maintenance organizations, aerodromes, air navigation service providers, personnel licensing, and other components of civil aviation.

Figure 1

Proposed Five-Level HFACS-SSGO Framework

LEVEL 5 – STATE SAFETY GOVERNANCE & OVERSIGHT				
State Safety Governance & Regulatory Framework	State Safety Capability & Resources	Certification & Regulatory Control	Safety Surveillance, Safety Intelligence & Risk Management	Safety Intervention & Resolution

▼

LEVEL 4 – ORGANIZATIONAL INFLUENCES		
Resource Management	Organizational Climate	Organizational Process

▼

LEVEL 3 – UNSAFE SUPERVISION			
Inadequate Supervision	Planned Inappropriate Operations	Failure to Correct Known Problems	Supervisory Violations

▼

LEVEL 2 – PRECONDITIONS FOR UNSAFE ACTS		
Environmental Factors	Condition of Operators	Personnel Factors

▼

LEVEL 1 – UNSAFE ACTS	
Errors	Violations

Note. Adapted and extended from the HFACS framework developed by Wiegmann and Shappell (2003). The proposed HFACS-SSGO framework retains the original four-level HFACS hierarchy while introducing SSGO as a fifth analytical level. Although positioned above Organizational Influences to preserve the hierarchical structure of HFACS, SSGO represents latent State-level governance and oversight conditions that may influence all four traditional HFACS levels. Such influences are expected to be most evident at the Organizational Influences and Unsafe Supervision levels, while also potentially affecting Preconditions for Unsafe Acts and, indirectly, frontline Unsafe Acts.

Coding Procedure

The coding process consisted of four sequential stages. First, the complete CENIPA (2026) final report was reviewed to develop a comprehensive understanding of the accident sequence, investigation findings, and operational, organizational, and institutional context. Second, contributing factors identified in the report were coded according to the four traditional HFACS levels (Shappell et al., 2007) and their established categories and definitions. Coding was limited to findings explicitly supported by evidence presented in the investigation, and each coded item was assigned to the HFACS level and category that best represented the underlying active failure or latent condition.

Third, State-level factors documented in the investigation were evaluated using the proposed SSGO level of HFACS-SSGO. Each factor was classified according to the five SSGO categories and definitions presented in Table 1. State-level factors were coded only when the CENIPA (2026) report provided evidence linking the identified condition to a State governance or oversight function; the existence of a regulatory responsibility alone was not considered sufficient to classify a factor as an SSGO influence. Finally, the classifications across all five levels were examined collectively to identify relationships among SSGO conditions, organizational influences, supervisory practices, preconditions for unsafe acts, and frontline unsafe acts. The analysis did not assume that relationships occurred only between adjacent levels or represented a linear causal sequence; rather, it examined whether and how conditions identified at one level were associated with conditions identified elsewhere in the framework within the broader accident context. Cross-level relationships were identified only when supported by evidence contained in the CENIPA final report and were not inferred solely from the hierarchical position of factors within HFACS-SSGO.

Relationships Between SSGO and HFACS Levels

Following classification, qualitative cross-level associations among the five analytical levels were examined to assess how SSGO conditions may have influenced, enabled, reinforced, or failed to mitigate conditions identified within the traditional HFACS levels. Particular attention was given to associations between SSGO and the higher-order HFACS levels of Organizational Influences (Level 4) and Unsafe Supervision (Level 3), while recognizing that SSGO conditions may also be associated, directly or indirectly, with Preconditions for Unsafe Acts (Level 2) and Unsafe Acts (Level 1).

A qualitative cross-level association was identified only when supported by evidence documented in the CENIPA final report (2026). No direct causal relationship or strictly sequential progression across the five levels was assumed. The identification of an SSGO condition therefore did not, by itself, imply that the State or regulatory authority caused or contributed to the accident; rather, cross-level associations were identified only when the available evidence supported an association between the State-level condition and safety-relevant conditions identified within the traditional HFACS levels.

Analytical Rigor

To enhance analytical rigor, the author and three independent subject-matter experts with professional and research experience in aviation safety, human factors, accident investigation, and related disciplines independently reviewed and classified the factors identified in the CENIPA final report. For Levels 1 through 4, classifications followed the established HFACS categories and definitions. For Level 5, reviewers applied the five SSGO categories and definitions developed in this study and presented in Table 1. Following independent classification, coding decisions were compared across reviewers. Consistent with previous HFACS research employing consensus classification (Patterson & Shappell, 2010), differences were discussed collectively until consensus was reached. Coding decisions were based on the narrative, sequence of events, factual information, analysis, findings, and conclusions documented in the CENIPA (2026) final report.

Findings and Discussion

Contributing factors documented in the CENIPA (2026) investigation were classified using the proposed HFACS-SSGO framework, which combines the four traditional HFACS levels (Shappell & Wiegmann, 2000) with the proposed fifth level, SSGO. The findings are presented sequentially by analytical level, followed by an integrated discussion examining relationships across the five levels. The following sections present the factors identified at each level and examine their relationships within the broader accident context.

Unsafe Acts

Unsafe Acts represent the active failures of frontline operators and constitute the HFACS level most directly associated with the accident sequence. Within the original framework, unsafe acts are classified as errors, skill-based, decision, or perceptual or as violations, which involve departures from established rules, procedures, or other authoritative guidance (Shappell & Wiegmann, 2000; Wiegmann & Shappell, 2003). Analysis of the CENIPA findings (2026) identified unsafe acts attributable to the flight crew involving decision errors, skill-based errors, and violations. These included flight planning and operational decision-making in forecast icing conditions; management of airspeed and aircraft performance; monitoring and response to Aircraft Performance Monitoring (APM) indications; execution of abnormal and stall-recovery procedures; formal reporting of a known Airframe De-Icing system malfunction; and engagement in non-operational conversation that diverted attention from operation-related cues during a critical period of the flight. The latter was provisionally classified as an exceptional violation, as the available evidence supports a discrete departure from appropriate cockpit discipline but does not establish that such behavior was habitual or organizationally tolerated. No perceptual errors were identified based on the available evidence. Table 2 summarizes the identified unsafe acts, their HFACS classifications (Shappell et al., 2007), and the supporting evidence documented by CENIPA (2026).

Table 2
HFACS Level 1 – Unsafe Acts

HFACS Category	Unsafe Act Identified	Evidence / Operational Significance
Decision Error	Acceptance/continuation of the flight at FL170 despite forecast severe icing conditions	Meteorological information available before and during the flight indicated severe icing along the route and relevant altitude range. The crew's planning and operational decisions did not adequately account for the hazard associated with the forecast icing conditions.
Decision Error	Failure to take timely action to leave or avoid severe icing as aircraft performance deteriorated	Despite continued icing, an Airframe De-Icing fault, decreasing airspeed, and progressive performance degradation, timely action was not taken to exit or avoid the hazardous icing environment.
Skill-Based Error	Failure to maintain the prescribed minimum airspeed in icing conditions	Airspeed progressively decreased despite prescribed icing-related airspeed requirements and increasingly evident aircraft-performance degradation.
Skill-Based Error	Inadequate monitoring and response to APM advisories and alerts	Successive CRUISE SPEED LOW advisories and later DEGRADED PERFORMANCE and INCREASE SPEED indications provided cues of progressive performance deterioration without an adequate or timely crew response.
Exceptional Violation (provisional)	Engagement in non-operational/personal conversation during a period of degraded aircraft performance and icing-related system concerns	After an exchange concerning activation of the De-Icing systems, the pilots resumed personal conversation. CENIPA concluded that conversations related to the PIC's personal life affected flight-crew performance and diverted attentional focus from operation-related cues. The classification is provisional because the available evidence supports a discrete departure from appropriate cockpit discipline but does not establish a habitual or organizationally tolerated practice.
Routine Violation	Failure to execute the prescribed DE ICING AIRFRAME FAULT procedure	Following the Airframe De-Icing fault, the prescribed abnormal procedure was not fully executed; the crew repeatedly reset the system and did not complete all required procedural actions.
Routine Violation	Failure to execute prescribed responses to APM performance-degradation indications	Required procedural responses associated with progressive APM indications, including DEGRADED PERFORMANCE and INCREASE SPEED, were not executed as prescribed.

HFACS Category	**Unsafe Act Identified**	**Evidence / Operational Significance**
Routine Violation	Failure to formally record the known Airframe De-Icing malfunction in the TLB	The crew was aware of the Airframe De-Icing malfunction but it was not formally entered in the Technical Logbook. CENIPA documented recurrent nonreporting of technical discrepancies and evidence consistent with normalization of this practice.
Skill-Based Error	Failure to execute an effective stall-recovery response	During the loss-of-control sequence, the prescribed stall-recovery response was not effectively accomplished; control inputs did not achieve the required reduction in angle of attack and recovery from the aerodynamic stall.

Note. Technical Logbook (TLB)

Preconditions for Unsafe Acts

Preconditions for Unsafe Acts represent environmental, operator, and personnel-related conditions that can shape or degrade frontline performance and increase the likelihood of errors or violations (Wiegmann & Shappell, 2003). Within HFACS, these conditions are organized into three broad categories: Environmental Factors, Conditions of Operators, and Personnel Factors. Analysis of the CENIPA (2026) findings identified preconditions associated with the icing environment, aircraft systems, crew cognitive state, workload, and crew coordination. These conditions did not constitute unsafe acts themselves but formed the operational context within which the Level 1 errors and violations occurred. Table 3 presents the identified preconditions, their HFACS classifications, and the supporting CENIPA evidence.

Table 3

HFACS Level 2 – Preconditions for Unsafe Acts

HFACS Category	Precondition Identified	Evidence / Operational Significance
Physical Environment	Severe icing / adverse meteorological conditions	The aircraft encountered atmospheric conditions conducive to severe icing. Ice accretion increased aerodynamic drag and contributed to progressive airspeed and performance degradation, creating a demanding operational environment.
Technological Environment	Degraded Airframe De-Icing capability	The aircraft was dispatched with the Airframe De-Icing system inoperative under Minimum Equipment List (MEL) provisions and subsequently experienced an Airframe De-Icing fault. The degraded system capability increased the operational significance of the icing encounter and reduced available protection against ice accretion.
Adverse Mental State	Complacency / reduced appreciation of the developing threat	CENIPA discussed complacency in relation to the crew's behavior and the developing icing scenario. The progressive deterioration was not met with a commensurate escalation in threat recognition and corrective action.
Adverse Mental State	Degraded situational awareness	The crew did not adequately integrate and project the significance of the evolving operational cues, including the icing encounter, Airframe De-Icing system status, decreasing airspeed, APM indications, and progressive deterioration of aircraft performance. This reduced understanding of the developing aircraft state impaired timely recognition of the escalating threat and selection of appropriate corrective actions.
Adverse Mental State	Attentional diversion associated with personal/non-operational conversation	CENIPA concluded that conversations concerning the PIC's personal life affected flight-crew performance and diverted attentional focus from operation-related cues. This occurred while icing-related system and aircraft-performance concerns were developing.
Crew Resource Management	Deficiencies in communication, coordination, monitoring, and shared threat and error management	Crew interactions did not consistently produce effective cross-checking, challenge, shared situational understanding, or coordinated response to the developing icing and performance threat. The exchange concerning the De-Icing systems, followed by renewed personal conversation, illustrates weaknesses in maintaining a common operational focus.

Unsafe Supervision

Unsafe Supervision encompasses supervisory actions or omissions that create or permit conditions conducive to unsafe frontline performance. HFACS classifies these factors as inadequate supervision, planned inappropriate operations, failure to correct known problems, and supervisory violations (Shappell & Wiegmann, 2000; Wiegmann & Shappell, 2003). Analysis of the CENIPA (2026) findings identified supervisory deficiencies involving training and proficiency oversight, management of recurring aircraft technical discrepancies, maintenance oversight, and continued operations under degraded technical conditions. Particularly significant were deficiencies in ensuring that known Airframe De-Icing and other system discrepancies were formally documented, effectively addressed, and prevented from recurring. Table 4 summarizes the identified supervisory factors and supports CENIPA (2026) evidence.

Table 4

HFACS Level 3 - Unsafe Supervision

Supervisory Factor	HFACS Classification	CENIPA Evidence / Operational Significance
Deficiencies in flight crew training and proficiency assurance	Inadequate Supervision	CENIPA documented training and proficiency issues relevant to crew preparation and performance in icing-related operations, recognition and management of aircraft performance degradation, application of abnormal procedures, and stall recognition and recovery. These findings indicate limitations in supervisory processes intended to ensure that flight crews possessed and maintained the competencies required to manage abnormal and high-risk operating conditions.
Deficiencies in maintenance supervision and control	Inadequate Supervision	Maintenance activities were performed in some instances without consultation of the applicable technical manuals and without required inspector-mechanic supervision. At secondary bases, personnel did not always have direct access to required technical documentation and sometimes relied on informal guidance from more experienced mechanics. These conditions reduced assurance that maintenance was performed and controlled in accordance with established requirements.
Recurrent or known Airframe De-Icing discrepancies were not effectively corrected	Failure to Correct Known Problems	Airframe De-Icing discrepancies had occurred before the accident flight, while informal verbal reporting and inconsistent Technical Logbook documentation weakened the process through which recurring faults were formally identified, tracked, and corrected. The persistence of a safety-significant technical condition despite prior indications represents a failure to ensure effective resolution of a known equipment problem.
Continued operation with degraded Airframe De-Icing capability under restrictive conditions	Planned Inappropriate Operations	The MEL permitted dispatch with an Airframe De-Icing system failure only for a limited period and subject to operational restrictions, including that flight into forecast icing conditions was not permitted. Continued operation with this degraded capability therefore required effective planning, maintenance control, and operational coordination to ensure compliance with the applicable restrictions and timely rectification.
Encouragement and tolerance of noncompliance with formal	Supervisory Violation	CENIPA identified an established practice in which flight crews did not formally record aircraft malfunctions in the TLB and found that this practice was encouraged by the company and directed toward pilots. The

Supervisory Factor	HFACS Classification	CENIPA Evidence / Operational Significance
aircraft discrepancy-reporting requirements		informal process placed pressure on pilots-in-command to avoid discrepancy entries that could result in prolonged aircraft unavailability for corrective maintenance. CENIPA further determined that the practice contravened civil aviation regulatory procedures and contributed to normalization of operational deviations.
Acceptance of maintenance and aircraft-release practices that circumvented established requirements	Supervisory Violation	CENIPA documented maintenance and MEL management practices in which technical discrepancies could be recorded as resolved or operational tests used to restore serviceability without appropriate corrective action, effectively extending allowable rectification periods. The report also identified replacement of an inoperative component with another component known to be malfunctioning and subsequent aircraft dispatch. These practices contributed to operation under knowingly degraded technical conditions beyond established regulatory limitations.

Note. MEL = Minimum Equipment List.

Organizational Influences

Organizational Influences represent latent conditions originating at the highest level of the original HFACS framework that can shape supervisory practices, operational conditions, and frontline performance. Within HFACS, these influences are classified as Resource Management, Organizational Climate, and Organizational Process (Wiegmann & Shappell, 2003). Analysis of the CENIPA (2026) findings identified organizational factors across all three categories, including a permissive safety climate characterized by normalization of procedural deviations and pressure to maintain operational continuity; limitations in maintenance staffing, technical resources, and support; and deficiencies in discrepancy reporting, maintenance control, flight crew training and proficiency management, operational risk management, and implementation and use of the operator’s SMS. Collectively, these findings indicate that the conditions associated with the accident extended beyond individual supervisory or frontline actions and were embedded within broader organizational structures, priorities, and processes. Table 5 summarizes the identified organizational influences, their HFACS classifications (Shappell et al., 2007), and the supporting CENIPA (2026) evidence.

Table 5

HFACS Level 4 - Organizational Influences

HFACS Category	Organizational Influence Identified	Evidence / Operational Significance
Organizational Climate	Permissive safety culture and normalization of procedural deviations (normalization of deviance)	CENIPA described an organizational environment in which departures from established operational and maintenance procedures became recurrent and increasingly normalized. Informal discrepancy reporting, procedural noncompliance, deferred corrective actions, and continued operation with degraded technical conditions reflected organizational norms that weakened adherence to safety requirements and diminished the perceived significance of noncompliance. This pattern is consistent with the normalization of deviance, whereby repeated acceptance of procedural departures gradually becomes embedded in organizational practice.
Organizational Climate	Organizational pressure prioritizing aircraft availability and operational continuity	CENIPA found that avoidance of formal TLB entries was encouraged by the company and directed toward pilots, creating pressure to avoid records that could result in aircraft being unavailable for corrective maintenance. Operational continuity therefore influenced compliance with established safety and maintenance processes.
Resource Management	Inadequate maintenance staffing and availability of qualified personnel	CENIPA documented limitations in the availability of qualified maintenance personnel, including circumstances in which maintenance activities were conducted without appropriate inspector-mechanic supervision. Personnel limitations and demanding work conditions reduced the organization's capacity to consistently provide the qualified human resources required for effective maintenance control.
Resource Management	Inadequate maintenance technical resources and support at secondary bases	Secondary maintenance bases did not consistently have direct access to required technical documentation, appropriate tooling, or equivalent technical support. Personnel sometimes relied on informal guidance from more experienced mechanics, increasing the potential for improvised maintenance practices and reducing assurance of standardized maintenance performance.
Organizational Process	Deficiencies in aircraft discrepancy reporting and technical traceability	Aircraft discrepancies, including Airframe De-Icing faults, were sometimes communicated verbally rather than formally entered in the TLB. This weakened organizational processes for documenting recurrent

HFACS Category	Organizational Influence Identified	Evidence / Operational Significance
		discrepancies, maintaining technical traceability, initiating corrective maintenance, and ensuring that unresolved conditions were appropriately controlled.
Organizational Process	Deficiencies in maintenance-control and MEL-management processes	CENIPA documented practices involving MEL management, recording discrepancies as resolved or restoring serviceability without appropriate corrective action, and operation under knowingly degraded technical conditions beyond established limitations. These practices weakened processes intended to ensure continuing airworthiness and timely resolution of technical discrepancies.
Organizational Process	Deficiencies in flight crew training and proficiency-management processes	Although required recurrent training had been completed, CENIPA's findings regarding crew performance in icing operations, management of performance degradation, abnormal procedures, and stall recovery raise concerns regarding the effectiveness of organizational processes for assuring that required competencies were maintained and effectively transferable to line operations.
Organizational Process	Deficiencies in operational risk management and support for icing hazards	CENIPA found that available safety information concerning performance degradation associated with ice accretion was not consistently incorporated into operational risk management. The Operations Control Center also did not provide real-time meteorological support to flight crews, limiting organizational support for identifying and mitigating icing-related operational risk.
Organizational Process	Deficiencies in Safety Management System (SMS) implementation and organizational use of safety information	CENIPA identified limitations in the implementation and maturity of the operator's SMS. Recurring technical and operational information, including Airframe De-Icing discrepancies, Aircraft Performance Monitoring (APM) events, and procedural deviations, was not consistently transformed into actionable safety intelligence to support hazard identification, risk assessment, decision-making, organizational learning, and effective corrective action, consistent with ICAO's Safety Intelligence principles (ICAO, 2025b).

Note. APM = Aircraft Performance Monitoring; SMS = Safety Management System

State Safety Governance and Oversight

The proposed fifth level, SSGO, extends the analysis beyond the traditional HFACS (Shappell et al., 2007) focus on the operating organization to examine State-level governance and oversight influences relevant to the accident. Using the five SSGO categories developed in this study, the analysis examined conditions associated with State safety governance and regulatory framework, capability and resources, certification and regulatory control, safety surveillance, safety intelligence and risk management, and safety intervention and resolution (ICAO, 2018, 2024, 2025a, 2025b). CENIPA (2026) documented substantial regulatory surveillance of the operator and multiple actions taken by the Brazilian National Civil Aviation Agency (ANAC) in response to identified deficiencies. However, recurrent operational, maintenance, airworthiness, and safety-management deficiencies persisted despite their visibility to the oversight system. Several of these deficiencies corresponded to organizational conditions identified at HFACS Level 4 (Shappell & Wiegmann, 2000), particularly those involving maintenance control, discrepancy reporting, management of degraded aircraft conditions, and safety risk management. The SSGO analysis therefore examined whether State-level conditions documented in the investigation were associated with the persistence or insufficient mitigation of safety-relevant conditions identified elsewhere within HFACS-SSGO (Table 6).

Table 6

Proposed Level 5 – State Safety Governance and Oversight Influences

SSGO Category	State Safety Governance/Oversight Influence Identified	Evidence / Operational Significance
State Safety Governance and Regulatory Framework	Limited integration of recurring safety indicators into broader State safety governance	CENIPA documented recurring technical, maintenance, malfunction-reporting, MEL, and organizational deficiencies relevant to the operator's safety performance. Although these matters were subject to regulatory oversight, their recurrence indicates limitations in how dispersed safety information was integrated and interpreted at the broader State-governance level to identify an accumulating pattern of systemic risk.
Safety Surveillance, Safety Intelligence, and Risk Management	Recurring safety signals persisted despite recurrent regulatory surveillance	ANAC conducted recurrent oversight and identified deficiencies involving maintenance, airworthiness, MEL management, malfunction reporting, and organizational processes. The persistence or recurrence of related deficiencies indicates limitations in the effectiveness of surveillance in integrating multiple findings and safety signals into a coherent assessment of the operator's evolving risk profile.
Safety Surveillance, Safety Intelligence, and Risk Management	Insufficient escalation of oversight in response to recurring and interacting risk indicators	The oversight record contained multiple indicators relevant to technical reliability, maintenance control, discrepancy reporting, and organizational practices. Although regulatory actions were taken, the continued recurrence and interaction of these indicators suggest limitations in the escalation of State safety risk-management responses as the operator's risk picture developed.
Safety Intervention and Resolution	Corrective, precautionary, and enforcement actions did not achieve sustained resolution of recurring safety deficiencies before the accident	ANAC took corrective, precautionary, and enforcement actions in response to identified deficiencies. However, CENIPA documented the persistence or recurrence of safety-significant practices and technical and organizational deficiencies. The issue is therefore not an absence of regulatory action, but the effectiveness and sustained resolution of identified safety issues before the accident.

Note 1. These findings represent higher-level latent influences and do not imply a direct linear causal relationship between State oversight activities and the accident. The analysis distinguishes the existence of regulatory surveillance and intervention from their effectiveness, integration, escalation, and ability to achieve sustained resolution of recurring safety signals.

Note 2. The SSGO findings presented in Table 6 represent the author's interpretation and classification of evidence documented throughout the CENIPA Final Report (CENIPA, 2026). Although the entire report informed the analysis, particular attention was given to CENIPA's documentation of ANAC surveillance activities and recurring nonconformities (pp. 125-130), the analysis of regulatory oversight and operator safety performance (pp. 206-210), and the safety recommendations addressing ANAC's State-level risk-management processes (pp. 253-255).

HFACS-SSGO Integration

The integrated analysis suggests that the VoePass Flight 2283 accident (CENIPA, 2026) cannot be adequately understood through the flight crew's actions alone. At the operational level, decision errors, skill-based errors, and violations involved icing-related decision-making, airspeed and aircraft-performance management, procedural execution, and stall recovery. These unsafe acts occurred amid severe icing, degraded Airframe De-Icing capability, reduced situational awareness, attentional diversion, complacency, and CRM deficiencies involving communication, coordination, monitoring, and shared threat and error management. These Level 1 unsafe acts and Level 2 preconditions were associated with Level 3 unsafe supervision conditions involving flight crew proficiency assurance, maintenance supervision, ineffective resolution of recurrent technical discrepancies, and continued operation under degraded technical conditions. Supervisory conditions also included tolerance or facilitation of noncompliant reporting and maintenance practices. These conditions were embedded within Level 4 organizational influences involving weaknesses in the company's safety culture, reflected in the normalization of procedural deviations, pressure favoring aircraft availability and operational continuity, and limitations in maintenance resources and technical support. Additional weaknesses involved discrepancy reporting, maintenance and MEL management, training and proficiency management, icing-risk management, and SMS implementation. Collectively, the HFACS findings depict interacting active failures and latent conditions extending from the flight deck through the operator's supervisory and organizational systems (CENIPA, 2026; Li & Harris, 2006; Shappell & Wiegmann, 2000; Wiegmann & Shappell, 2003).

A particularly important relationship across these levels concerned the availability of safety information and its conversion into effective safety action. Before the accident, recurrent Airframe De-Icing discrepancies, maintenance and MEL-related issues, informal discrepancy-reporting practices, APM events, and procedural deviations provided information relevant to the operator's evolving risk profile. However, these recurring safety signals were not consistently integrated into organizational safety intelligence supporting effective hazard identification, risk assessment, organizational learning, corrective action, and sustained risk control (ICAO, 2025a, 2025b). This pattern links Level 4 weaknesses in SMS, maintenance control, discrepancy management, and organizational processes with Level 3 failures to correct known problems. These systemic conditions allowed technical and operational vulnerabilities to persist within the environment in which Level 2 preconditions and Level 1 unsafe acts emerged (CENIPA, 2026; Shappell et al., 2007).

The proposed SSGO level extends the analysis beyond the operator's organizational boundary. Several vulnerabilities identified at HFACS Levels 3 and 4 had also become visible to the regulatory system before the accident. ANAC had conducted surveillance, documented deficiencies involving maintenance, airworthiness, MEL management, malfunction reporting, and organizational processes, and implemented corrective, precautionary, and enforcement measures (CENIPA, 2026). The issue, therefore, was not an absence of regulatory activity. Rather, the persistence or recurrence of deficiencies raises questions about how multiple safety indicators were integrated, assessed, escalated, and ultimately resolved. This provides the central analytical connection between HFACS and SSGO. The proposed fifth level does not alter the explanatory logic of HFACS; rather, it expands the analytical scope to include the State safety system responsible for overseeing the organizational defenses examined within the original framework. Accordingly, HFACS identifies vulnerabilities within the operator, whereas SSGO examines the State safety defenses intended to detect, constrain, and facilitate correction of those vulnerabilities before they contribute to accident occurrence. Level 5 does not establish a direct causal pathway between regulatory performance and flight crew actions; instead, it provides a structured means of examining how the effectiveness of State safety defenses may shape the organizational environment in which operational risks emerge. Specifically, SSGO makes visible State-level conditions that fall outside the traditional Organizational Influences level of HFACS, including regulatory governance and institutional capability, certification and regulatory control, State surveillance and safety intelligence, State-level safety risk management, and the escalation, intervention, and sustained resolution of identified safety deficiencies, consistent with ICAO principles and responsibilities for State safety oversight and safety management (ICAO, 2018, 2025a, 2025b).

From a practical perspective, HFACS-SSGO enables accident investigators, regulators, and safety analysts to examine not only how organizational failures developed within the operator, but also how State safety defenses identified, monitored, responded to, and resolved emerging safety risks. Consequently, the framework may assist in identifying opportunities for safety improvement that extend beyond the operator to the wider aviation system. The SSGO perspective also considers contextual State conditions that may shape the capacity to perform these regulatory functions. These conditions fall within State Safety Capability and Resources, which addresses the human, financial, technical, technological, and institutional resources necessary to fulfill State safety responsibilities (Table 1). Complementary government evidence indicates that Brazil's federal regulatory agencies were experiencing significant resource constraints shortly before the accident. In May 2024, approximately three months before the accident, the 11 Brazilian federal regulatory agencies jointly characterized their situation as critical. They reported an approximately 20% budget reduction and a personnel deficit in which more than 65% of positions across the agencies were vacant. The agencies warned that these conditions could compromise their regulatory activities (Brazil's National Health Surveillance Agency [Agência Nacional de Vigilância Sanitária - ANVISA], 2024). ANAC's specialist workforce further illustrates this institutional-capacity dimension. In July 2023, the Federal Government authorized a public competition for Civil Aviation Regulation Specialists, and ANAC subsequently conducted the selection process for 70 immediate vacancies (ANAC, 2023). However, the Federal Government did not authorize the appointment of the 70 successful candidates until October 25, 2024, more than two months after the accident (ANAC, 2024). Consequently, the planned reinforcement of ANAC's specialist workforce had not yet been realized at the time of the accident. Such conditions are relevant to SSGO because resource availability may influence the capacity and timeliness of surveillance, safety-risk analysis, regulatory intervention, and resolution of identified deficiencies (ICAO, 2018, 2025a).

Importantly, these circumstances were not identified by CENIPA (2026) as contributing factors, and available evidence does not establish that resource limitations affected ANAC's oversight of VoePass. They are therefore treated as higher-order contextual conditions rather than accident causes or evidence of regulatory failure. Their relevance to SSGO lies in their potential to shape State regulatory capacity and the environment in which safety oversight is performed. A subsequent development provides a broader illustration of this relationship. In June

2026, a R$24 million (~US$4.5 million) Federal Government budget block led ANAC to report an approximately 40% reduction in surveillance activities and the suspension of certain certification activities (Gaier, 2026). Although unrelated to the VoePass accident, this example illustrates the State Safety Capability and Resources category by showing how resource availability can affect a civil aviation authority's capacity to perform safety-critical functions, including surveillance, safety risk management, and resolution of safety issues (ICAO, 2018, 2025a).).

Taken together, the HFACS-SSGO analysis depicts a multilevel system of safety defenses rather than a linear causal chain. HFACS traces the accident from frontline unsafe acts through their preconditions to supervisory and organizational vulnerabilities. SSGO extends the analytical boundary to the State system responsible for overseeing those organizational systems and considers broader governmental conditions that may shape its capacity to perform that role. In the VoePass case (CENIPA, 2026), the bridge between HFACS and SSGO is the recurrence and visibility of safety signals. Deficiencies persisted within the operator, while several became known to the regulatory system before the accident. The extended framework permits examination of how those vulnerabilities were addressed internally, how the regulatory system responded, and what State-level conditions may have shaped that response. It does not assume that conditions identified at each level directly caused the accident. The proposed SSGO level therefore does not transfer responsibility from the operator or diminish the significance of frontline performance. Rather, it extends the systems boundary across operational, supervisory, organizational, regulatory, and State-governance levels. This integration permits examination of how vulnerabilities may persist across safety defenses and whether those defenses effectively identify, constrain, escalate, or resolve recurring safety risks.

Conclusion

This study examined the VoePass Flight 2283 accident through a multilevel systems approach combining the four HFACS levels (Shappell et al., 2007) with a proposed fifth level addressing SSGO (Figure 1). In addressing the first research question, the analysis identified contributing factors across all four traditional HFACS levels, encompassing unsafe acts, preconditions for unsafe acts, unsafe supervision, and organizational influences. In addressing the second research question, the analysis identified State-level safety governance and oversight factors extending beyond the traditional organizational boundary of HFACS, demonstrating how the proposed SSGO level broadens the systemic analysis to the external State safety system.The findings suggest that the accident cannot be adequately understood by examining flight crew performance or any single system level in isolation (CENIPA, 2026; Wiegmann & Shappell, 2003). At the operational level, decision errors, skill-based errors, and routine violations occurred amid severe icing, degraded Airframe De-Icing capability, reduced situational awareness, complacency, reduced vigilance toward recurrent aircraft-performance alerts, and ineffective crew coordination. Higher-level conditions involved flight crew training and proficiency assurance, maintenance supervision, unresolved technical discrepancies, continued operation under degraded aircraft conditions, and supervisory acceptance of practices departing from established requirements. Organizational influences included weaknesses in safety culture, normalization of procedural deviations, pressure favoring operational continuity, resource limitations, deficiencies in maintenance and discrepancy management, and weaknesses in organizational risk management and SMS implementation. Collectively, these findings illustrate how frontline active failures were associated with increasingly latent supervisory and organizational conditions within the operator (CENIPA, 2026; Shappell & Wiegmann, 2000; Wiegmann & Shappell, 2003).

Extending the analysis beyond the traditional HFACS (Shappell et al., 2007) organizational boundary revealed an additional layer of safety defenses. CENIPA documented that ANAC had previously detected significant maintenance, airworthiness, operational, and organizational deficiencies through regulatory surveillance and had implemented corrective, precautionary, and enforcement measures (CENIPA, 2026). The issue was therefore not the absence of regulatory activity, but rather the persistence and recurrence of identified deficiencies despite regulatory visibility and intervention. This raises questions about how recurring safety signals were integrated, assessed, escalated, and sustainably resolved. This relationship provides the central analytical bridge between HFACS and SSGO. HFACS identifies vulnerabilities within the operator, while SSGO examines the State safety defenses intended to detect, constrain, and facilitate correction of those vulnerabilities. SSGO also considers State capability and resources that may shape the performance of these functions. These functions include surveillance, resolution of safety issues, State safety risk management, and State safety assurance (ICAO, 2018, 2025). Importantly, the proposed extension does not imply that State oversight or State resource conditions directly caused the VoePass accident. Rather, SSGO expands the analytical boundary to examine the external safety system within which the operator functioned and the State-level conditions potentially affecting that system.

Several limitations constrain the interpretation of these findings. The study was primarily a documentary analysis of the CENIPA Final Report (2026) and was therefore limited by the evidence collected, analyzed, and reported by the official investigation. No independent interviews, observations, or comprehensive internal records from VoePass or ANAC were available to independently verify or expand the identified relationships. Complementary government sources provided additional context for State capability and resources, but they do not establish that resource constraints affected ANAC's specific oversight of VoePass. Accordingly, those conditions should be interpreted as contextual SSGO findings rather than accident causes or evidence of regulatory failure. HFACS coding also involves researcher interpretation, particularly at higher levels where individual findings may reasonably intersect multiple categories. Moreover, SSGO is a proposed conceptual extension rather than an empirically validated fifth HFACS level. Its categories and relationships with the original HFACS levels therefore require testing beyond this case. Finally, this single-case analysis concerns one accident, operator, and national safety oversight system, limiting the generalizability of its findings. Despite these limitations, the study demonstrates the potential value of extending HFACS beyond the operator when evidence supports examination of the broader State safety system. The HFACS-SSGO framework provides a structured approach for examining multilevel safety defenses without assuming a linear causal progression. If further validated, HFACS-SSGO has the potential to complement existing HFACS applications by providing investigators with a structured means of examining how State safety governance and oversight interact with organizational, supervisory, and operational safety defenses within complex aviation systems. Future research should apply the framework across additional accidents, operational contexts, and regulatory environments to evaluate its reliability, validity, generalizability, and analytical utility.

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