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**SEGURIDAD
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FUERZA AEROSPAZIAL
COLOMBIANA



**ESCUELA DE
POSTGRADOS
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Boletín No.8 Briefing Seguridad Operacional Maestría en Seguridad Operacional 2026

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Editorial



La investigación en Seguridad Operacional constituye un eje fundamental para comprender, fortalecer y proyectar las capacidades del sector aeronáutico frente a los desafíos de un entorno cada vez más complejo, dinámico y exigente. En este contexto, la Maestría en Seguridad Operacional continúa consolidando espacios académicos orientados a la generación, aplicación y socialización de conocimiento, con el propósito de aportar al mejoramiento continuo de la gestión del riesgo y la cultura de seguridad.

Esta nueva edición del *Briefing de Seguridad Operacional* reúne productos académicos que reflejan el avance investigativo, formativo y aplicado de la Cohorte X.. En sus páginas se presentan los informes derivados de estancias prácticas, así como avances de investigación formativa que evidencian el proceso de apropiación científica y el fortalecimiento de competencias investigativas en los estudiantes.

La Escuela de Postgrados de la Fuerza Aeroespacial Colombiana reafirma, a través de esta publicación, su responsabilidad con la formación de alto nivel, la consolidación de una cultura investigativa y el desarrollo de conocimiento pertinente para el sector aeroespacial.

En este camino, la Maestría en Seguridad Operacional continúa avanzando como un programa estratégico, comprometido con la calidad, la innovación académica y la construcción de capacidades al servicio de la seguridad, la institución y el país.

Mayor Francine Pineda Mongui
Directora Programa Maestría Seguridad Operacional

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SECCIÓN 1

INFORMES DE ESTANCIAS PRÁCTICAS

► Cohorte X



1 ESTANCIAS PRACTICAS

Las estancias prácticas constituyen un componente fundamental dentro del proceso de formación posgradual de la Maestría en Seguridad Operacional, en la medida en que permiten articular los conocimientos adquiridos en el aula con escenarios reales de observación, análisis y aplicación profesional. A través de este ejercicio, los estudiantes fortalecen su capacidad para comprender problemáticas asociadas a la gestión de la seguridad operacional, reconocer dinámicas institucionales y proponer reflexiones orientadas al mejoramiento continuo de los procesos aeronáuticos.

Más que un requisito académico, las estancias prácticas representan un espacio de aproximación crítica a la realidad operacional. En ellas, el estudiante tiene la posibilidad de contrastar la teoría con la práctica, analizar procesos existentes, reconocer factores que inciden en la gestión del riesgo y fortalecer competencias para la seguridad operacional.

Por MY. Francine Pineda Mongui

1.1 Diseño instruccional y estructuración académica de la asignatura Factor Humano en Operaciones I para la Maestría en Seguridad y Gestión del Riesgo en Operaciones bajo el modelo pedagógico UNAQ



Fuente: Valencia Rocchi, Y. (2026). Registro fotográfico de reuniones de coordinación académica y actividades de vinculación institucional realizadas durante la estancia práctica en la Universidad Aeronáutica de Querétaro (UNAQ) [Fotografía]. Archivo personal.

La estancia práctica desarrollada por la estudiante Yazmín Valencia Rocchi en la Universidad Aeronáutica de Querétaro tuvo como propósito apoyar el diseño instruccional y la estructuración académica de la asignatura Factor Humano en Operaciones I. Su alcance incluyó contenidos sobre factor humano, comportamiento humano en sistemas complejos, ergonomía, error humano, violaciones operacionales, modelos de causalidad de accidentes y análisis sistémico del error, siguiendo el modelo pedagógico institucional fundamentado en el aprendizaje experiencial de Kolb y los eventos de instrucción de Gagné (UNAQ, s.f.; Kolb, 1984; Gagné, 1985). Asimismo, se definieron objetivos de aprendizaje, resultados esperados, estrategias didácticas, entregables y criterios de evaluación para cada unidad temática, orientados a su implementación en la plataforma Moodle de la institución (UNAQ, 2024).

La metodología se basó en investigación aplicada y diseño instruccional bajo el modelo ADDIE, centrándose en las fases de análisis, diseño y desarrollo de materiales académicos para entornos virtuales (UNAQ, s.f.). Las actividades desarrolladas incluyeron la revisión del programa oficial, competencias, bibliografía y lineamientos institucionales; sesiones de formación en diseño instruccional; inducción a Moodle; visita a laboratorios de realidad virtual; exploración de herramientas IA como apoyo académico; elaboración de la planeación académica de la asignatura; construcción de guías de aprendizaje; y verificación de recursos digitales. Como productos de la estancia se entregaron una planeación académica completa y veinticuatro guías de actividades listas para su implementación, evidenciando el cumplimiento total de los objetivos propuestos y recomendándose fortalecer la retroalimentación interinstitucional y el aprovechamiento de recursos tecnológicos en futuros procesos formativos (UNAQ, 2024; UNAQ, s.f.).

1.2 Apoyo al Diseño instruccional y planeación académica para la asignatura “Evolución de la Seguridad Operacional y Normatividad Internacional”

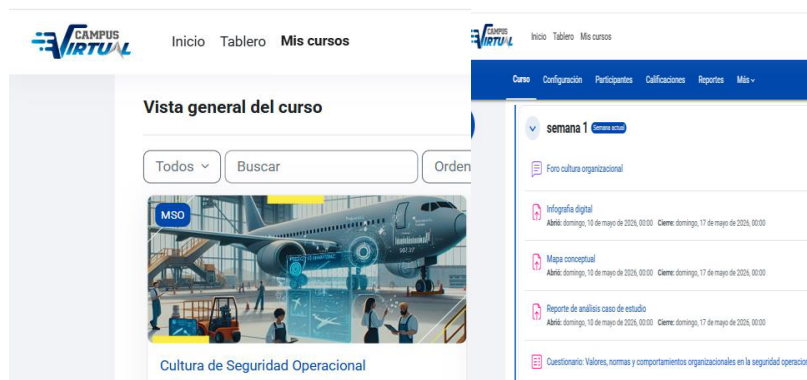


Fuente: Torres Pastrana, M. E. (2026). Registro fotográfico de actividades académicas y recorrido institucional en instalaciones de la Universidad Aeronáutica de Querétaro (UNAQ) [Fotografía]. Archivo personal.

La estancia práctica realizada por la estudiante Mónica Eugenia Torres Pastrana en UNAQ estuvo orientada al diseño instruccional y la planeación académica de la asignatura *Evolución de la Seguridad Operacional y Normatividad Internacional*, perteneciente al programa de Maestría en Seguridad y Gestión del Riesgo en Operaciones. Su alcance comprendió la estructuración de las primeras semanas del curso mediante la aplicación del modelo institucional de diseño instruccional, integrando resultados de aprendizaje, actividades síncronas y asíncronas, estrategias de andamiaje, metacognición, evaluación auténtica y recursos para entornos virtuales. Las actividades desarrolladas incluyeron análisis curricular, revisión normativa, observación de clases virtuales, capacitación en Moodle, formación en diseño instruccional, construcción de secuencias didácticas basadas en aprendizaje por proyectos, elaboración de instrumentos de evaluación, diseño de recursos digitales y desarrollo de actividades centradas en la evolución de la seguridad operacional, la normatividad internacional, los organismos reguladores y el análisis de casos reales asociados a la gestión de la seguridad operacional (UNAQ, 2024; UNAQ, s.f.).

Como resultado, se consolidó la planeación académica de las semanas iniciales de la asignatura y se desarrolló un conjunto de recursos para su implementación en Moodle, entre ellos rúbricas analíticas, escalas estimativas, formatos de análisis operacional, diagramas regulatorios, guías de actividades, plantillas académicas, materiales audiovisuales y recursos para el aprendizaje autónomo. Asimismo, se integraron contenidos y casos reales relacionados con la OACI, los SARPs, los PANS y la gestión de la seguridad operacional, fortaleciendo la contextualización de los aprendizajes en escenarios operacionales reales. Se destaca además el fortalecimiento de competencias en diseño instruccional, análisis normativo, evaluación del aprendizaje, gestión académica, uso pedagógico de plataformas LMS y aplicación de herramientas tecnológicas como la realidad virtual e IA (OACI, 2018; UNAQ, 2024; UNAQ, s.f.).

1.3 Diseño y planeación didáctica de la asignatura "Cultura en Seguridad Operacional" para una maestría de seguridad operacional de la Universidad Aeronáutica de Querétaro, México.



La estancia práctica desarrollada por el estudiante TS Jaime Augusto Vega Martínez en la UNAQ estuvo orientada al diseño y estructuración de la asignatura Cultura de la Seguridad Operacional, concebida para una maestría en seguridad operacional con aplicación en los ámbitos aéreo, marítimo y terrestre. El trabajo se fundamentó en una investigación cualitativa basada en revisión bibliográfica, análisis de contenido y estudio de documentos normativos y pedagógicos, complementada con la aplicación de la metodología de Robert Gagné para el diseño de estrategias de aprendizaje (Gagné, 1985). Entre las actividades desarrolladas se encuentran la elaboración de módulos de aprendizaje, la organización secuencial de contenidos, la definición de estrategias instruccionales, el diseño de actividades en línea, la construcción de rúbricas y métodos de evaluación, así como la configuración de la asignatura en la plataforma Moodle de la UNAQ con materiales, actividades e instrucciones para los estudiantes (UNAQ, s.f.).

Los resultados evidenciaron el cumplimiento satisfactorio del objetivo principal mediante la entrega de una planeación didáctica integral, estructurada en módulos que abarcan desde los fundamentos teóricos hasta el análisis de las diferentes culturas de seguridad operacional. Como producto concreto, la asignatura quedó organizada en la plataforma virtual de la UNAQ, lista para su implementación por parte del cuerpo docente. Adicionalmente, se consolidó una propuesta pedagógica orientada al desarrollo de competencias en cultura de seguridad operacional, se creó un repositorio de materiales de apoyo compuesto por presentaciones, artículos de investigación y recursos audiovisuales, y se fortalecieron los conocimientos del estudiante en planeación didáctica, diseño curricular y gestión de cursos virtuales. El informe destaca además que la experiencia permitió integrar la teoría educativa con la seguridad operacional, favoreciendo la transmisión de conceptos como factores humanos, factores contribuyentes, cultura justa y subculturas de seguridad con impacto en la cultura organizacional aeronáutica (OACI, 2018; Reason, 2010).

1.4 Fortalecimiento de la seguridad operacional mediante la actualización del programa de prevención de FO y la implementación de herramientas de verificación de infraestructura en la CIAC



Fuente: Márquez Fonseca, S. (2026). *Actividades de inspección, verificación de infraestructura y fortalecimiento de la gestión de seguridad operacional en instalaciones de mantenimiento aeronáutico de la CIAC* [Fotografía]. Archivo personal elaborado durante la estancia práctica.

La estancia práctica desarrollada por el estudiante Santiago Márquez en el área de Seguridad Operacional del departamento GASOP de la Corporación de la Industria Aeronáutica de Colombia (CIAC) estuvo orientada al fortalecimiento de los procesos de seguridad operacional mediante la actualización del programa de prevención de objetos extraños (FO) y la implementación de herramientas para la verificación de infraestructura. Bajo un enfoque cualitativo y descriptivo, se analizaron necesidades operacionales identificadas a partir de reportes de seguridad y requisitos normativos aplicables.

Los resultados obtenidos evidenciaron avances concretos en el fortalecimiento de la gestión de la seguridad operacional dentro de la CIAC. Como principal producto se diseñó una lista de chequeo estandarizada para infraestructura e instalaciones, herramienta que permitió establecer criterios formales para la identificación de peligros, la verificación de condiciones operacionales y la generación de reportes de seguridad. Asimismo, se actualizó el Manual de Prevención de FO incorporando lineamientos, controles y procedimientos alineados con los requerimientos del documento Airbus TA.SU.IS.M005_3_0_FOD y con los RAC 145 y RAC 219, fortaleciendo la gestión documental y los mecanismos de prevención de objetos extraños en áreas de mantenimiento aeronáutico. Adicionalmente, la carta de cumplimiento desarrollada permitió identificar el nivel de alineación entre los estándares del cliente y los procedimientos internos de la organización, generando insumos para futuras acciones de mejora, seguimiento y cumplimiento normativo dentro de la corporación (Airbus, s.f.; UAEAC, 2025a; UAEAC, 2025b).

1.5 Diseño instruccional de la asignatura Gestión de la Seguridad Operacional en entornos virtuales de posgrado

La estancia práctica desarrollada por el estudiante Andrés Felipe Garzón Combita en la Universidad Aeronáutica de Querétaro (UNAQ) estuvo orientada al diseño estructural académico de la Maestría en Seguridad y Gestión del Riesgo en Operaciones, mediante la participación en el diseño instruccional de la asignatura Gestión de la Seguridad Operacional en modalidad asincrónica y mixta. El trabajo se fundamentó en el modelo educativo institucional de la UNAQ, basado en competencias, la taxonomía de Bloom revisada, el aprendizaje experiencial de Kolb y los eventos de instrucción de Gagné, integrando componentes de impacto del aprendizaje, nuevo conocimiento, andamiaje y metacognición.

La imagen muestra una de las planeaciones académicas desarrolladas durante la estancia, en la que se evidencian los resultados de aprendizaje, las estrategias instruccionales, las actividades de aprendizaje y los mecanismos de evaluación diseñados para la asignatura Gestión de la Seguridad Operacional (Hernández Sampieri & Mendoza, 2023; Krathwohl, 2002; Kolb, 2015; Gagné et al., 2005).

Fuente: Universidad Aeronáutica de Querétaro (UNAQ). (2026). *Formato de planeación didáctica para cursos virtuales – Gestión de la Seguridad Operacional*. Elaboración propia durante la estancia práctica.

Los resultados demostraron el cumplimiento de los objetivos planteados mediante el desarrollo de cuatro planeaciones didácticas completas, la estructuración de 117 de 144 actividades académicas previstas (82 % del proyecto general) y el diseño de 36 actividades para la asignatura Gestión de la Seguridad Operacional, de las cuales 30 fueron implementadas en la plataforma Moodle, alcanzando un avance del 83,33 %. Asimismo, se incorporaron metodologías innovadoras como estudios de caso, análisis de accidentes, briefings ejecutivos, podcasts técnicos y actividades apoyadas en inteligencia artificial, fortaleciendo competencias en diseño instruccional, educación virtual, gestión del riesgo operacional y uso pedagógico de plataformas LMS. El informe destaca además el fortalecimiento de la cooperación académica entre la EPFAC y la UNAQ, así como el potencial de estas experiencias para impulsar procesos de innovación educativa y formación avanzada en seguridad operacional (Creswell & Creswell, 2023; Hernández Sampieri & Mendoza, 2023).

1.6 Informe técnico “Elaboración instructivo GH-JEAES-FR-303 FORMATO DE OBSERVACIÓN MOSA y aplicativo Microsoft PowerApps”

La estancia práctica desarrollada por el estudiante Miguel Moreno en la Inspección General de la Fuerza Aeroespacial Colombiana (IGEFA), específicamente en la Subdirección de Fiabilidad Operacional, estuvo orientada al fortalecimiento del programa Military Oriented Safety Audit (MOSA) mediante la elaboración del instructivo para el diligenciamiento del formato GH-JEAES-FR-303 y el desarrollo de un aplicativo digital para la captura y gestión de información operacional. El trabajo se fundamentó en la revisión de documentación técnica emitida por la Organización de Aviación Civil Internacional (OACI) y la Federal Aviation Administration (FAA) relacionada con los programas Line Operations Safety Audit (LOSA), el modelo Threat and Error Management (TEM) y los principios de los Sistemas de Gestión de la Seguridad Operacional (SMS). Entre las actividades desarrolladas se destacan el análisis de modelos internacionales de observación operacional, el diseño de la arquitectura funcional del aplicativo en Microsoft PowerApps que se muestra en la imagen a continuación, la estructuración de bases de datos integradas con SharePoint y la elaboración del instructivo técnico para la gestión, almacenamiento y tratamiento de la información obtenida durante las observaciones MOSA (FAA, 2006; OACI, 2002; OACI, 2018).

The image displays two screenshots of a Microsoft PowerApps interface. The left screenshot shows a screen titled 'Estados no deseados (UAS)' with a home icon and a back arrow. Below the title, there is a green banner with the text 'Seleccione el estado no deseado (UAS) a registrar o editar'. In the center, there is a graphic of an aircraft with a warning sign and the text 'UAS ESTADOS NO DESEADOS'. At the bottom, there are four blue buttons labeled 'Registro de 1.(UAS)', 'Registro de 2.(UAS)', 'Registro de 3.(UAS)', and 'Registro de 4.(UAS)'. The right screenshot shows a screen titled 'Estado no deseado 1(UAS)' with a home icon and a back arrow. It contains several input fields: 'U1 ID del UAS' with a dropdown menu showing 'UAS 1'; 'U1 ¿Error enlazado?' with a dropdown menu showing 'E1'; 'U1 Descripción del UAS' with a text input field containing 'Prueba celular'; 'U1 Código UAS' with a dropdown menu showing '4 Incorrecta configuración - Motores'; 'U1 Respuesta al UAS' with a dropdown menu showing 'Buscar elementos'; and 'U1 Resultado del UAS' with a dropdown menu showing 'Buscar elementos'. At the bottom, there is a red button labeled 'Registrar otro (UAS)'.

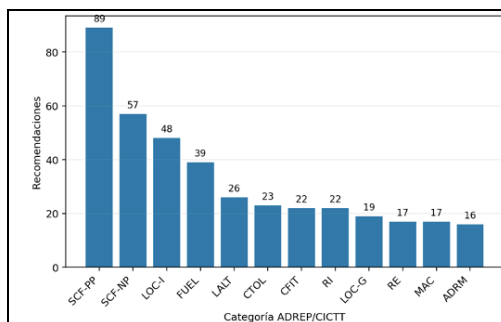
Fuente: Moreno, M. (2026). Interfaces del aplicativo Microsoft PowerApps para el registro de amenazas, errores y estados no deseados del programa MOSA [Captura de pantalla]. Elaboración propia durante la estancia práctica en la Inspección General de la Fuerza Aeroespacial Colombiana (IGEFA).

Los resultados evidenciaron el cumplimiento satisfactorio de los objetivos propuestos mediante la entrega de un prototipo piloto funcional capaz de digitalizar el proceso de

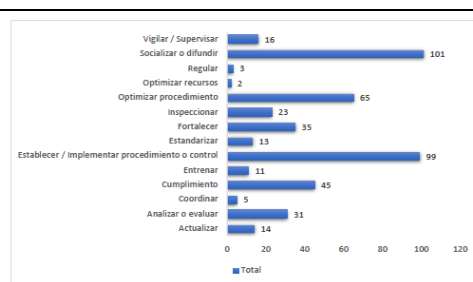
observación MOSA, fortaleciendo la disponibilidad, trazabilidad y confiabilidad de los datos operacionales. El aplicativo permitió estandarizar el registro de amenazas, errores y estados no deseados conforme a las taxonomías del modelo TEM, garantizar la confidencialidad de la información recolectada y facilitar su integración con herramientas institucionales de análisis como Excel, Power BI y SharePoint. Asimismo, el proyecto fortaleció la aplicación de los principios de toma de decisiones basada en datos (*Data Driven Decision Making*) y aportó una solución tecnológica escalable para futuras auditorías MOSA dentro de la Fuerza Aeroespacial Colombiana. El informe concluye que la herramienta desarrollada constituye un apoyo significativo para la consolidación de una seguridad operacional proactiva, predictiva y no punitiva, alineada con los principios de Cultura Justa y mejora continua en la aviación militar (OACI, 2018; Poulouse et al., 2024).

1.7 Clasificación taxonómica de las recomendaciones derivadas de los informes de accidentes e incidentes aéreos en Colombia (2022-2026)

La estancia práctica desarrollada por el estudiante Andrés Alirio Castro Díaz en la Dirección Técnica de Investigación de Accidentes (DIACC) de la Aeronáutica Civil estuvo orientada a la clasificación taxonómica de las recomendaciones de seguridad operacional derivadas de accidentes, incidentes graves e incidentes aéreos ocurridos en Colombia entre 2022 y 2026. El trabajo se fundamentó en los principios de gestión de la seguridad operacional promovidos por la OACI y en las taxonomías ADREP/CICTT, ECCAIRS y SRVSOP para el análisis de información aeronáutica. Las actividades incluyeron la depuración y normalización de una base de datos para fortalecer la trazabilidad y la verificación de eficacia de las acciones derivadas de las investigaciones (OACI, 2018; SRVSOP, 2020).



Fuente Elaboración propia durante la estancia práctica en la Dirección Técnica de Investigación de Accidentes (DIACC), a partir de la clasificación taxonómica de recomendaciones derivadas de accidentes e incidentes aéreos en Colombia (2022-2026).



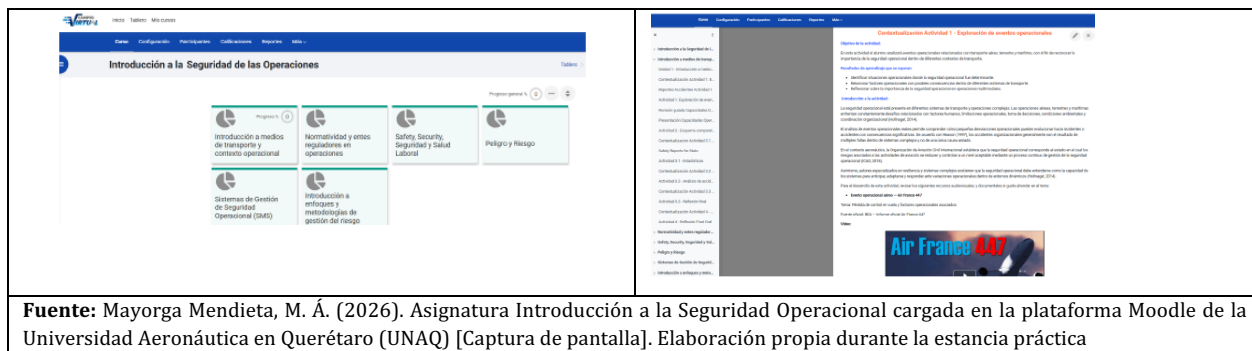
Fuente: Castro Díaz, A. A. (2026). Elaboración propia durante la estancia práctica en la Dirección Técnica de Investigación de Accidentes (DIACC), con base en la clasificación taxonómica de recomendaciones derivadas de accidentes e incidentes aéreos en Colombia (2022-2026).

Los resultados que se presentan en las imágenes anteriores evidenciaron que, las categorías SCF-PP (89 recomendaciones), SCF-NP (57), LOC-I (48) y FUEL (39) concentraron

la mayor cantidad de acciones derivadas de las investigaciones, indicando la necesidad de fortalecer la confiabilidad técnica, el control operacional y la gestión del combustible. Asimismo, la segunda gráfica muestra que las acciones más frecuentes fueron socializar o difundir información (101), implementar procedimientos y controles (99) y optimizar procedimientos (65), evidenciando que las oportunidades de mejora se concentran principalmente en procesos organizacionales (OACI, 2018; ECCAIRS, 2018).

1.8 Desarrollo e implementación de la asignatura Introducción a la Seguridad Operacional en el entorno virtual Moodle de la UNAQ

La estancia práctica desarrollada por el estudiante Miguel Ángel Mayorga Mendieta en la Universidad Aeronáutica en Querétaro (UNAQ) estuvo orientada al diseño instruccional y virtualización de la asignatura Introducción a la Seguridad Operacional para su implementación en la plataforma Moodle. Las actividades desarrolladas incluyeron el análisis y ajuste de la malla curricular, la estructuración de contenidos temáticos, la elaboración de planeaciones didácticas, la definición de objetivos y resultados de aprendizaje, y el diseño de actividades académicas fundamentadas en principios de diseño instruccional, niveles cognitivos y estrategias de evaluación orientadas al aprendizaje significativo. Asimismo, se apoyó la organización de los contenidos dentro del campus virtual institucional, integrando recursos digitales, actividades de aprendizaje y herramientas de seguimiento académico (Creswell & Creswell, 2023; Smith & Ragan, 2005; Tyler, 1949).



Como resultado, se consolidó una asignatura completamente estructurada y cargada en Moodle para su futura implementación. La Figura 3 muestra la organización de las unidades académicas dentro del campus virtual de la UNAQ, donde se observan módulos relacionados con introducción a medios de transporte, normatividad y entes reguladores, safety y security, peligro y riesgo, sistemas de gestión de la seguridad operacional e introducción a metodologías de gestión del riesgo. En la parte inferior de la imagen se evidencia el contenido interno de una de las unidades, compuesto por actividades, recursos

de consulta y materiales de apoyo diseñados para favorecer el aprendizaje autónomo y la interacción del estudiante con los conceptos fundamentales de seguridad operacional. El proyecto permitió fortalecer competencias en diseño instruccional, virtualización de contenidos y gestión de entornos educativos digitales aplicados a la formación aeronáutica (Creswell & Creswell, 2023; Smith & Ragan, 2005).

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SECCIÓN **2** | **AVANCES DE INVESTIGACIÓN FORMATIVA**

► Cohorte X



2 AVANCES DE INVESTIGACIÓN FORMATIVA

Este capítulo presenta dos avances de investigación desarrollados en el marco de la Maestría en Seguridad Operacional, enfocados en el análisis de problemáticas actuales que impactan la gestión del riesgo y la seguridad aérea. Estas investigaciones abordan, desde perspectivas complementarias, la aplicación de herramientas tecnológicas para fortalecer los sistemas de gestión de la seguridad operacional y el análisis de fenómenos operacionales asociados a la gestión del tránsito aéreo, aportando evidencia y elementos de reflexión orientados a mejorar la toma de decisiones, la identificación de riesgos y el fortalecimiento de una cultura de seguridad basada en la prevención y la mejora continua.

De los reportes a la Acción: Estandarización de Categorías de Alto Riesgo para fortalecer la seguridad Operacional Naval



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Línea de investigación: Gestión de la Seguridad Operacional

RESUMEN

En la industria de la aviación comercial y militar, por lo general se busca evitar que los peligros causen pérdidas humanas mediante la implementación de una serie de barreras preventivas y de mitigación (Hollnagel, 2004). En ese sentido, la Organización de Aviación Civil Internacional (OACI, 2022), establece la reducción continua de los riesgos de seguridad operacional, siendo su primer objetivo la identificación de las Categorías de Alto Riesgo (High Risk Categories – HRC), junto con la definición de las áreas que requieren intervención prioritaria, siendo una etapa clave dentro de la planificación en aviación, ya que permite concentrar los recursos y esfuerzos a los procesos donde existe mayor exposición al riesgo, favoreciendo una gestión más anticipativa y alineada con los principios del Sistema de Gestión de Seguridad Operacional (SMS) y evitando una actuación únicamente reactiva frente a los eventos.

Para lograr una identificación eficaz de dichas categorías, es indispensable apoyarse en información proveniente de múltiples fuentes, que reflejen de manera objetiva y confiable el comportamiento real de la operación, dentro de las cuales se incluyen las investigaciones de accidentes e incidentes, los reportes de seguridad operacional, los registros de mantenimiento relacionados con la aeronavegabilidad, así como el seguimiento al desempeño operacional. A esto se suman los resultados de inspecciones, auditorías, encuestas y estudios técnicos y recomendaciones de los protocolos de psicología aplicados anualmente a las tripulaciones de vuelo, los cuales permiten identificar tendencias, reconocer factores que influyen en la ocurrencia de eventos y detectar condiciones que, aunque no siempre son evidentes, pueden incrementar el riesgo dentro de la operación. (OACI, 2022) (p-7)

La investigación radicó en identificar, evaluar y proponer un modelo de estandarización institucional de las Categorías de Alto Riesgo (H.R.C), respaldado por el esquema taxonómico de ocurrencias operacionales vigente establecido por la Autoridad de Aviación Civil y Militar (OACI, 2018) y el Sistema Regional de Cooperación para la vigilancia de la Seguridad Operacional (SRVSOP, 2020), que articulado con la implementación del enfoque de Cultura Justa (Dekker, 2016) y (Rasmussen, 1982) se ajusta a la Aviación Naval de Colombia (AVNA), permitiendo no solo la adecuación y clasificación de eventos, sino también el fortalecimiento y respaldo institucional a las tripulaciones de vuelo de AVNA en el desarrollo de las operaciones aéreas. Esto, contribuyó en la identificación sistemática de tendencias de riesgo y la priorización de acciones preventivas frente a sucesos asociados a factores humanos, fallas mecánicas, condiciones operacionales y causas externas.

La metodología se desarrolló inicialmente con un proceso de recolección de información basado en el método exploratorio secuencial, partiendo de información cualitativa generada de los reportes de sucesos operacionales realizados en la AVNA a lo largo de los años 2022 al 2025 para su posterior análisis y evaluación de riesgos, mencionado

proceso resulta en los datos cuantitativos de la estructuración taxonómica de acuerdo a su causa raíz discriminada por peligros y área de injerencia, método mencionado por Creswell J.W. y Creswell J.D. (2023). De igual forma, presenta un carácter no experimental al no verse afectada la composición ni estructura de los datos obtenidos de los reportes operacionales, donde únicamente se obtuvo la información, pero no alteró las condiciones existentes, como lo menciona Arias (2012).

Por otra parte, se hizo uso del enfoque mixto, como lo mencionan Creswell J.W. y Creswell J.D. (2023), buscando combinar las fortalezas de cada uno de los enfoques, tanto cualitativo como cuantitativo, con el fin de desarrollar una comprensión más sólida del problema o gestionar correctamente los instrumentos en la recolección de datos y posterior su evaluación y postulación del modelo a utilizar, que dió solución al problema planteado durante la investigación, al superar las limitaciones de cada uno y finalmente combinarlos.

El proceso investigativo inició con la recopilación y revisión de reportes de seguridad operacional generados entre los años 2022 y 2025. Posteriormente, los datos son clasificados y distribuidos dentro de categorías de alto riesgo previamente definidas en el Plan Global para la Seguridad Operacional de la Aviación (GASP) (OACI, 2022) y la Unidad Administrativa Especial Aeronáutica Civil (UAEAC, 2024), permitiendo la evaluación mediante herramientas de gestión de riesgo y análisis estadísticos que facilitaron determinar tendencias, frecuencia y nivel de criticidad de los eventos reportados, desde la experiencia operativa.

Posterior se aplica un cuestionario de identificación de brechas planteado por el sistema regional de vigilancia de seguridad operacional (SRVSOP) de la OACI y la Aeronáutica civil (UAEAC), para determinar qué tan apropiado y en qué condiciones se encuentra el sistema de gestión de riesgo en etapa de construcción de la AVNA, mencionada herramienta es diligenciada por los tripulantes que la componen la institución en las diferentes antigüedades y especialidades.

Los resultados de la investigación evidencian una proporción de cerca del 30% de los eventos registrados no concuerdan a su peligro, categoría o constructo teórico de acuerdo a las taxonomías establecidas por las instituciones rectoras en el ámbito de aviación, cerca del 80% de los reportes no cuenta con una estructura sólida para poder ejecutar una correcta gestión de riesgos por parte del Comando de la AVNA, lo que demuestra la necesidad de fortalecer los mecanismos de gestión del riesgo y de establecer criterios uniformes para la clasificación y seguimiento de los sucesos. Durante el lapso de tiempo seleccionado, menos del 1% de los reportes resultó en fatalidad, cerca del 2% en accidentes graves, un aproximado al 10 % en accidentes leves con daños a las aeronaves y el resto del porcentaje en incidentes o situaciones irregulares, tomando como referencia los modelos de causalidad de accidentes de Heinrich (1941) y Bird (1985).



Estos hallazgos permiten evidenciar la dispersión en los criterios de categorización, situación que limita la capacidad institucional para identificar patrones recurrentes de riesgo y detectar deficiencias en la orientación adecuada de las acciones preventivas. Lo anterior pone de manifiesto, además, la relevancia de contar con una taxonomía clara y estandarizada, conocida y aplicada por el personal que participa en los procesos de seguridad operacional, así como por los tripulantes de la Aviación Naval (AVNA).

En la práctica, se observa que los reportes operacionales son elaborados de manera reiterada sin que, en algunos casos, el personal tenga pleno conocimiento del origen del evento, su composición o la estructura adecuada para la identificación clara del error o la desviación, tal como lo describen Wiegmann y Shappell (2003). Esta situación se ve agravada, cuando se evidencia la no aplicación correcta de la cultura justa, lo que conduce a la generación de juicios a nivel organizacional o directivo sin una estructura definida, basados solo en apreciaciones personales.

En conclusión, el modelo propuesto en la investigación permite mejorar la trazabilidad de los datos, la toma de decisiones y la implementación de medidas preventivas dentro del sistema de gestión de seguridad operacional de la Aviación Naval. El impacto de esta investigación se refleja en el fortalecimiento de los procesos de gestión del riesgo operacional en la AVNA, al proporcionar una estructura metodológica para la identificación, clasificación y seguimiento de los eventos de seguridad operacional. Como productos asociados se genera una propuesta de estandarización de las HRC, la formulación de un Plan de Acción para la Seguridad Operacional de la AVNA, así como herramientas analíticas que permiten mejorar la interpretación de los reportes de seguridad operacional, contribuyendo a la reducción de la probabilidad de ocurrencias, la optimización de los recursos destinados al mantenimiento y la preservación de la vida humana y de los medios aeronáuticos institucionales.

Palabras clave: Aeronáutica, Regulación Aeronáutica, sistema de seguridad, Medidas de seguridad

From Reports to Action: Standardizing High-Risk Categories to Strengthen Naval Operational Safety

ABSTRACT

In the commercial and military aviation industry, efforts are generally focused on preventing hazards from causing loss of life through the implementation of a series of preventive and mitigation barriers (Hollnagel, 2004). In this regard, the International Civil Aviation Organization (ICAO, 2022) establishes the continuous reduction of operational safety risks, identifying High Risk Categories (HRC) as its primary objective, along with defining areas that require priority intervention. This represents a key stage in aviation planning, as it enables the concentration of resources and efforts on processes with the highest exposure to risk, promoting a more anticipatory management approach aligned with the principles of the Safety Management System (SMS), and avoiding a solely reactive response to events.

To achieve effective identification of these categories, it is essential to rely on information from multiple sources that objectively and reliably reflect the actual behavior of operations. These sources include accident and incident investigations, operational safety reports, maintenance records related to airworthiness, and operational performance monitoring. Additionally, results from inspections, audits, surveys, technical studies, and recommendations derived from psychological protocols applied annually to flight crews are incorporated. These elements make it possible to identify trends, recognize factors influencing the occurrence of events, and detect conditions that, although not always evident, may increase operational risk (ICAO, 2022, p. 7).

The research focused on identifying, evaluating, and proposing a model for the institutional standardization of High-Risk Categories (HRC), supported by the current taxonomic framework of operational occurrences established by the Civil and Military Aviation Authority—namely the International Civil Aviation Organization (ICAO, 2018)—and the Sistema Regional de Cooperación para la Vigilancia de la Seguridad Operacional (SRVSOP, 2020). This model, articulated with the implementation of the Just Culture approach, as proposed by Dekker (2016) and Rasmussen (1982), is tailored to the Colombian Naval Aviation (AVNA). It enables not only the adaptation and classification of events, but also the strengthening of institutional support for AVNA flight crews in the execution of air operations. This approach contributed to the systematic identification of risk trends and the prioritization of preventive actions addressing events associated with human factors, mechanical failures, operational conditions, and external causes.



The methodology was initially developed through an information collection process based on the sequential exploratory method, starting from qualitative data derived from operational occurrence reports generated within AVNA between 2022 and 2025. This was followed by risk analysis and evaluation, resulting in quantitative data obtained through taxonomic structuring according to root causes, categorized by hazards and areas of influence, as described by Creswell and Creswell (2023). Likewise, the study is characterized as non-experimental, as neither the composition nor the structure of the data obtained from operational reports was altered; instead, the data were observed and analyzed without modifying existing conditions, as noted by Arias (2012).

Furthermore, a mixed-methods approach was applied, as described by Creswell J.W. y Creswell J.D. (2023), aiming to combine the strengths of both qualitative and quantitative approaches. This integration allowed for the development of a more comprehensive understanding of the problem, as well as the proper management of data collection instruments, their subsequent evaluation, and the formulation of the proposed model. This approach ultimately addressed the research problem by overcoming the limitations of each method and effectively integrating them into a unified framework.

The research process began with the collection and review of operational safety reports generated between 2022 and 2025. Subsequently, the data were classified and distributed into High-Risk Categories previously defined in the Global Aviation Safety Plan (GASP) (ICAO, 2022) and by the Unidad Administrativa Especial de Aeronáutica Civil (UAEAC, 2024). This classification enabled evaluation through risk management tools and statistical analysis, facilitating the identification of trends, frequency, and the level of criticality of reported events, based on operational experience.

Subsequently, a gap identification questionnaire proposed by the Sistema Regional de Cooperación para la Vigilancia de la Seguridad Operacional (SRVSOP) of the International Civil Aviation Organization and the Unidad Administrativa Especial de Aeronáutica Civil (UAEAC) was applied to determine the level of adequacy and the current conditions of the risk management system under development within AVNA. This instrument was completed by the institution's flight crews, representing different levels of seniority and specialties.

The results of the research show that approximately 30% of the recorded events do not correspond to their associated hazard, category, or theoretical construct according to the taxonomies established by the governing aviation institutions. Likewise, nearly 80% of the reports lack a solid structure to enable effective risk management by the AVNA Command, highlighting the need to strengthen risk management mechanisms and establish uniform criteria for the classification and monitoring of occurrences. During the selected period, less than 1% of the reports resulted in fatalities, around 2% in serious accidents, approximately 10% in minor accidents involving aircraft damage, and the remaining percentage



corresponded to incidents or irregular situations, taking as reference the accident causation models of Heinrich (1941) and Bird (1985).

These findings highlight the dispersion in categorization criteria, a situation that limits the institution's ability to identify recurring risk patterns and detect deficiencies in the proper orientation of preventive actions. Furthermore, this underscores the importance of having a clear and standardized taxonomy, understood and applied by personnel involved in operational safety processes, as well as by flight crews within Naval Aviation (AVNA).

in practice, it is observed that operational reports are repeatedly prepared without, in some cases, personnel having a full understanding of the origin of the event, its composition, or the appropriate structure for clearly identifying the error or deviation, as described by Wiegmann and Shappell (2003). This situation is further aggravated when there is evidence of improper application of the Just Culture approach, leading to the generation of organizational or managerial judgments without a defined structure, based solely on personal interpretations.

In conclusion, the model proposed in this research enhances data traceability, decision-making, and the implementation of preventive measures within the Naval Aviation Safety Management System. The impact of this research is reflected in the strengthening of operational risk management processes within AVNA by providing a methodological framework for the identification, classification, and monitoring of operational safety events. As associated outputs, the study delivers a proposal for the standardization of High-Risk Categories (HRC), the formulation of an AVNA Operational Safety Action Plan, and analytical tools that improve the interpretation of operational safety reports. These contributions support the reduction of occurrence probability, the optimization of maintenance resources, and the preservation of human life and institutional aeronautical assets.

Keywords: Aviation, Aeronautical Regulation, Safety System, Safety Measures

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Uso de plataformas de planificación de recursos empresariales para la optimización del riesgo en aviación no tripulada



Fuente: Escorcía Venegas, M. (2024). Prueba Operacional de Aeronave No Tripulada para la logística de Insumos Médicos en Zona Remota – La Guajira [Fotografía]

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Línea de investigación: Gestión de la Seguridad Operacional - Gestión de riesgo.

RESUMEN

El crecimiento de las operaciones con Sistemas de Aeronaves No Tripuladas (UAS) en Colombia ha sido significativo, pasando de 220 solicitudes de operación en 2017 a 2376 en 2025 (UAEAC, 2026). Este incremento, impulsado por el desarrollo del marco regulatorio establecido en el RAC 100, ha generado la necesidad de fortalecer los sistemas de gestión de la seguridad operacional en las organizaciones operadoras de UAS (UAEAC, 2023). En este contexto, la gestión de riesgos se configura como un componente crítico, particularmente en lo relacionado con el reporte de eventos, la identificación de peligros y las gestiones de riesgo de seguridad operacional.

A pesar de esta necesidad, muchas organizaciones explotadoras de UAS continúan utilizando herramientas ofimáticas tradicionales como formularios digitales, procesadores de texto y hojas de cálculo para la gestión de la seguridad operacional, lo que limita la integración, trazabilidad y análisis sistemático de la información (Solano & Cruz, 2024). En contraste, el uso de plataformas de Planificación de Recursos Empresariales (ERP) en este sector es aún incipiente, debido a factores como costos de implementación, resistencia organizacional y desconocimiento de sus capacidades (Matende & Ogao, 2013).

Existe una brecha en la forma en que las organizaciones operadoras de UAS gestionan la información de seguridad operacional, particularmente en términos de integración de procesos y eficiencia en la gestión de riesgos, lo que plantea la necesidad de evaluar alternativas tecnológicas más robustas como los sistemas ERP (Pohludka et al., 2018). En consecuencia, el presente estudio adopta un enfoque metodológico mixto, con alcance descriptivo y diseño de triangulación concurrente (Sampieri et al., 2014), con el objetivo de evaluar la efectividad de un aplicativo desarrollado sobre una plataforma ERP para la gestión de la seguridad operacional en operaciones UAS.

La investigación se desarrolló a partir de dos fuentes principales: los reportes de seguridad operacional de una organización operadora de UAS en proceso de certificación bajo el RAC 100 y el juicio de un panel de ocho expertos en seguridad operacional y gestión de riesgos. Mediante una encuesta tipo Likert y una ficha de observación aplicada durante el uso de ambos sistemas, los expertos realizaron una evaluación comparativa entre herramientas ofimáticas tradicionales y un aplicativo basado en ERP, analizando variables como facilidad de uso, eficiencia en el registro de información, capacidad de integración y soporte a la toma de decisiones.

Los resultados obtenidos evidencian que el uso de herramientas ofimáticas presenta limitaciones en la trazabilidad de la información, la duplicidad de registros y las dificultades para la integración de procesos relacionados con la identificación de peligros y la gestión de riesgos. En contraste, el aplicativo desarrollado sobre la plataforma ERP presentó

valoraciones superiores en la totalidad de los ítems evaluados, lo que confirma un mejor desempeño general frente al formato implementado en Excel con VBA.

En términos estadísticos, se identificaron diferencias significativas en variables asociadas a la facilidad de uso, específicamente en la interacción ($p = 0.048$), la claridad de la interfaz ($p = 0.006$) y la navegación ($p = 0.018$), así como en la utilidad para la gestión de riesgos ($p = 0.033$) y el cumplimiento de las necesidades del usuario ($p = 0.049$). Estos resultados evidencian que el aplicativo no solo mejora la experiencia de uso, sino también su funcionalidad en el contexto de la gestión de la seguridad operacional.

Así mismo, los expertos destacaron que las soluciones basadas en ERP ofrecen ventajas en términos de control de acceso a la información, estandarización de procesos y fortalecimiento de la gestión de datos sensibles, aspectos fundamentales para la seguridad operacional. No obstante, también se identificaron desafíos asociados a su implementación, particularmente en lo relacionado con la adaptación organizacional y la capacitación de los usuarios.

Si bien no todas las variables presentaron diferencias estadísticamente significativas, se observa una tendencia consistente a favor del aplicativo ERP en la totalidad de las dimensiones analizadas. Este comportamiento se ve respaldado por el análisis no paramétrico mediante la prueba de Wilcoxon, aplicada debido al tamaño reducido de la muestra ($n = 8$) y a la violación del supuesto de normalidad en varias variables, lo cual refuerza la robustez de los resultados obtenidos.

En conjunto, estos hallazgos indican que la implementación de sistemas ERP en organizaciones operadoras de UAS contribuye significativamente al fortalecimiento de los sistemas de gestión de la seguridad operacional, al mejorar la usabilidad, la integración de procesos y la calidad de la información. Este aspecto resulta especialmente relevante en un contexto de crecimiento acelerado del sector, donde la gestión eficiente de la información constituye un factor crítico para la prevención de accidentes e incidentes y la toma de decisiones basadas en evidencia.

En términos prácticos, el estudio aporta evidencia empírica sobre la viabilidad del uso de plataformas ERP como herramientas de soporte para la gestión de riesgos en la aviación no tripulada, consolidándose como una solución tecnológica aplicable en organizaciones del sector.

Palabras clave: Aeronaves remotamente tripuladas, optimización de procesos, tecnología emergente, regulación aeronáutica colombiana, gestión de riesgos en UAS.

Use of Enterprise Resource Planning Platforms for Risk Optimization in Unmanned Aviation

ABSTRACT

Claro, te lo revisé únicamente en ****espacios, puntuación y formato****, sin cambiar la información ni el contenido.

The growth of operations involving Unmanned Aircraft Systems (UAS) in Colombia has been significant, increasing from 220 operation requests in 2017 to 2,376 in 2025 (UAEAC, 2026). This increase, driven by the development of the regulatory framework established under RAC 100, has created the need to strengthen operational safety management systems within UAS operating organizations (UAEAC, 2023). In this context, risk management emerges as a critical component, particularly in relation to event reporting, hazard identification, and operational safety risk management processes.

Despite this need, many UAS operating organizations continue to rely on traditional office tools such as digital forms, word processors, and spreadsheets for operational safety management, which limits the integration, traceability, and systematic analysis of information (Solano & Cruz, 2024). In contrast, the use of Enterprise Resource Planning (ERP) platforms in this sector remains incipient, due to factors such as implementation costs, organizational resistance, and limited awareness of their capabilities (Matende & Ogao, 2013).

A gap exists in the way UAS operating organizations manage operational safety information, particularly in terms of process integration and efficiency in risk management. This situation highlights the need to evaluate more robust technological alternatives, such as ERP systems (Pohludka et al., 2018). Accordingly, this study adopts a mixed-methods approach, with a descriptive scope and a concurrent triangulation design (Sampieri et al., 2014), aiming to evaluate the effectiveness of an application developed on an ERP platform for operational safety management in UAS operations.

The research was conducted based on two primary sources: operational safety reports from a UAS operating organization undergoing certification under RAC 100, and the judgment of a panel of eight experts in operational safety and risk management. Through a Likert-scale survey and an observation checklist applied during the use of both systems, the experts conducted a comparative evaluation between traditional office tools and an ERP-based application, analyzing variables such as ease of use, efficiency in data entry, integration capability, and decision-making support.

The results show that the use of office tools presents limitations in information traceability, record duplication, and difficulties in integrating processes related to hazard identification and risk management. In contrast, the application developed on the ERP platform achieved higher ratings across all evaluated items, confirming superior overall performance compared to the Excel-based format implemented with VBA.

From a statistical perspective, significant differences were identified in variables associated with ease of use, specifically interaction ($p = 0.048$), interface clarity ($p = 0.006$), and navigation ($p = 0.018$), as well as in usefulness for risk management ($p = 0.033$) and the fulfillment of user needs ($p = 0.049$). These results indicate that the application not only improves user experience but also enhances its functionality within the context of operational safety management.

Furthermore, the experts highlighted that ERP-based solutions offer advantages in terms of information access control, process standardization, and the strengthening of sensitive data management—key aspects for operational safety. However, challenges related to their implementation were also identified, particularly regarding organizational adaptation and user training.

Although not all variables showed statistically significant differences, a consistent trend favoring the ERP-based application was observed across all analyzed dimensions. This pattern is supported by non-parametric analysis using the Wilcoxon test, applied due to the small sample size ($n = 8$) and the violation of normality assumptions in several variables, thereby reinforcing the robustness of the findings.

Overall, these findings indicate that the implementation of ERP systems in UAS operating organizations significantly contributes to strengthening operational safety management systems by improving usability, process integration, and information quality. This is particularly relevant in a context of rapid sector growth, where efficient information management constitutes a critical factor for accident and incident prevention and evidence-based decision-making.

In practical terms, this study provides empirical evidence on the feasibility of using ERP platforms as support tools for risk management in unmanned aviation, consolidating them as a technological solution applicable to organizations within the sector.

Keywords: Remotely Piloted Aircraft (RPA), Process Optimization, Emerging Technology, Colombian Aeronautical Regulation, UAS Risk Management

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¿Qué revela un aterrizaje que nunca ocurrió? Aproximaciones Frustradas y Seguridad Operacional



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Línea de investigación: Gestión de la Seguridad Operacional

RESUMEN

¿Alguna vez ha sentido cómo un avión, justo antes de tocar pista, interrumpe su descenso y vuelve a elevarse inesperadamente? Para muchos pasajeros, este momento genera incertidumbre e incluso una sensación de temor. En aviación, sin embargo, esta maniobra tiene un nombre preciso: aproximación frustrada, el cual es un procedimiento que se ejecuta cuando no es posible completar la aproximación y el aterrizaje (Organización de Aviación Civil Internacional [OACI], 2016). Lejos de representar una falla, constituye una decisión deliberada orientada a preservar la seguridad del vuelo. No obstante, cuando estas maniobras comienzan a presentarse con mayor frecuencia en un mismo entorno operacional, resulta pertinente analizar las condiciones que las originan.

En el Aeropuerto de Cartagena, el 36% de las aproximaciones frustradas registradas entre 2021 y 2025 fueron originadas por pista ocupada, lo que evidencia que una proporción relevante de estas maniobras no responde a aproximaciones desestabilizadas, ni a condiciones meteorológicas adversas, sino a instrucciones emitidas por los controladores de tránsito aéreo (ATCO), quienes son responsables de garantizar la separación reglamentaria entre aeronaves de acuerdo con las características del espacio aéreo donde se desarrollan dichas operaciones (Unidad Administrativa Especial de Aeronáutica Civil [UAEAC], 2026a).

Este hallazgo permite inferir que una parte significativa de este fenómeno no está relacionada exclusivamente con el desempeño de las tripulaciones, sino con condiciones operacionales propias del entorno, asociadas a la gestión del tránsito aéreo y a la capacidad del sistema. En este contexto, la aproximación frustrada por pista ocupada se configura como una respuesta operativa para evitar escenarios de reducción de la separación entre aeronaves, particularmente en fases críticas del vuelo donde los márgenes de maniobra son limitados.

El aeropuerto Internacional Rafael Núñez de Cartagena se caracteriza por condiciones operacionales particulares, entre las que se destacan la alta densidad de tránsito, la ausencia de una calle de rodaje paralela a la pista y limitaciones de visibilidad desde la torre de control hacia los umbrales 01 y 19 debido a la presencia de árboles, cuyo reporte se encuentra en la información suplementaria oficial de las Publicaciones Aeronáuticas (AIP) (UAEAC, 2026b). Esto implica que la gestión táctica de las llegadas y salidas exija decisiones inmediatas que, en determinadas circunstancias, conducen a ordenar una aproximación frustrada como último recurso para restablecer los mínimos de separación reglamentarios y evitar la materialización de un evento no deseado.

A partir de esta problemática, la investigación se orienta a analizar las aproximaciones frustradas como un fenómeno operacional asociado a la ocupación de pista, con el propósito de identificar las condiciones operacionales que propician su ocurrencia y comprender su relación con la gestión del riesgo en la fase final del vuelo.



El estudio se desarrolló bajo un enfoque cualitativo de tipo exploratorio, mediante un estudio de caso aplicado al Aeropuerto Internacional Rafael Núñez de Cartagena. Los participantes fueron seleccionados intencionalmente entre controladores de tránsito aéreo y pilotos con experiencia directa en dicho entorno operacional. Para ello, se emplearon técnicas como el análisis de registros operacionales, la revisión documental, entrevistas semiestructuradas y grupos focales, lo que permitió una comprensión integral del fenómeno desde la perspectiva de los actores directamente involucrados (Hernández et al., 2014). La información recolectada fue organizada y analizada mediante procesos de categorización temática, orientados a identificar patrones y relaciones entre las condiciones operacionales y la ocurrencia de aproximaciones frustradas.

Los resultados evidencian que las aproximaciones frustradas por pista ocupada no responden a un factor aislado, sino que emergen de la interacción entre múltiples elementos del sistema. El tiempo de ocupación de pista, la disposición geométrica de la misma, ajustes tardíos en la trayectoria de aproximación, alta carga de trabajo tanto en cabina como en el control aéreo, decisiones tácticas y procedimientos adoptados en tiempo real por los controladores aéreos, revelan que la capacidad operativa de un aeropuerto es influida por dichos factores (Di Mascio et al., 2021).

Más allá de explicar por qué un avión no aterrizó, el análisis de estas maniobras permite comprender cómo el sistema responde ante condiciones de presión operacional. Desde el enfoque del modelo del queso suizo (Reason, 1997), las aproximaciones frustradas por pista ocupada pueden interpretarse como la última barrera disponible cuando otras defensas del sistema han sido superadas o debilitadas, y su recurrencia permite anticipar condiciones que, de no ser gestionadas adecuadamente, podrían escalar hacia eventos de mayor severidad (Heinrich, 1941). En un entorno donde la complejidad del tránsito aéreo continúa en aumento, interpretar adecuadamente estas señales puede marcar la diferencia entre una gestión reactiva y una gestión predictiva del riesgo (OACI, 2018).

Uno de los principales aportes del estudio radica en reconocer que las aproximaciones frustradas por pista ocupada pueden constituir una fuente de información clave dentro del Sistema de Gestión de la Seguridad Operacional (SMS), al evidenciar condiciones que afectan la eficiencia y seguridad del flujo de tránsito aéreo. Analizar estos eventos desde una perspectiva sistémica permite no solo comprender sus causas, sino también orientar acciones encaminadas a su mitigación y control.

Al tratarse de un estudio exploratorio en un contexto específico, esta investigación representa un primer acercamiento al análisis de las aproximaciones frustradas por pista ocupada en el entorno operacional colombiano, aportando elementos que pueden ser considerados en futuras investigaciones y en la toma de decisiones operacionales.

Palabras clave: Aproximación Frustrada, Control de Tránsito Aéreo, Seguridad Aérea y Cumplimiento Normativo.



What does a landing that never happened reveal?

Missed Approaches and Operational Safety

ABSTRACT

Have you ever noticed how an aircraft, just moments before touchdown, interrupts its descent and unexpectedly climbs again? For many passengers, this moment generates uncertainty and even a sense of apprehension. In aviation, however, this maneuver has a precise name: *missed approach*, defined as the procedure executed when it is not possible to complete the approach and landing (Organización de Aviación Civil Internacional [OACI], 2016). Far from representing failure, it is a deliberate decision aimed at preserving flight safety. However, when these maneuvers begin to occur more frequently within the same operational environment, it becomes necessary to analyze the conditions that give rise to them.

At Cartagena Airport, 36% of the missed approaches recorded between 2021 and 2025 were due to runway occupancy, indicating that a significant proportion of these maneuvers is not related to unstable approaches or adverse weather conditions, but rather to instructions issued by air traffic controllers (ATCOs), who are responsible for ensuring regulatory separation between aircraft in accordance with the characteristics of the airspace where such operations take place (Unidad Administrativa Especial de Aeronáutica Civil [UAEAC], 2026a).

This finding suggests that a significant portion of the phenomenon is not exclusively related to flight crew performance, but rather to operational conditions inherent to the environment, associated with air traffic management and system capacity. In this context, the missed approach due to runway occupancy emerges as an operational response to prevent scenarios involving reduced aircraft separation, particularly during critical phases of flight where maneuvering margins are limited.

Cartagena Airport is characterized by particular operational conditions, including high traffic density, the absence of a parallel taxiway, and limited visibility from the control tower toward runways 01 and 19 due to the presence of trees reported in the official supplementary information Aeronautical Publications (AIP) (UAEAC, 2026b). This implies that the tactical management of arrivals and departures requires immediate decision-making, which, under certain circumstances, leads to the instruction of a missed approach as a last resort to restore regulatory separation and prevent the occurrence of an undesired event.

Based on this problem, the present research aims to analyze missed approaches as an operational phenomenon associated with runway occupancy, with the purpose of identifying

the operational conditions that trigger their occurrence and understanding their relationship with risk management during the final phase of flight.

The study was conducted under a qualitative exploratory approach through a case study applied to Rafael Núñez International Airport in Cartagena. Participants were intentionally selected among air traffic controllers and pilots with direct experience in this operational environment. Techniques such as operational data analysis, document review, semi-structured interviews, and focus groups were employed, allowing for a comprehensive understanding of the phenomenon from the perspective of the directly involved actors (Hernández et al., 2014). The collected information was organized and analyzed through thematic categorization processes aimed at identifying patterns and relationships between operational conditions and the occurrence of missed approaches.

The results show that missed approaches due to runway occupancy do not respond to a single isolated factor but rather emerge from the interaction of multiple elements within the system. Runway occupancy time, runway geometric configuration, late adjustments in the approach trajectory, high workload both in the cockpit and in air traffic control, as well as tactical decisions and procedures adopted in real time by controllers, reveal that airport operational capacity is influenced by these factors (Di Mascio et al., 2021).

Beyond explaining why an aircraft did not land, the analysis of these maneuvers provides insight into how the system responds under operational pressure. From the Swiss cheese model perspective (Reason, 1997), missed approaches due to runway occupancy can be interpreted as the last available barrier when other system defenses have been overcome or weakened. Their recurrence also allows anticipating conditions that, if not properly managed, it could escalate into higher-severity events (Heinrich, 1941). In an environment where air traffic complexity continues to increase, properly interpreting these signals can make the difference between reactive and predictive risk management (OACI, 2018).

One of the main contributions of this study lies in recognizing that missed approaches due to runway occupancy can serve as a key source of information within the Safety Management System (SMS), by highlighting conditions that affect the efficiency and safety of air traffic flow. Analyzing these events from a systemic perspective not only allows for a better understanding of the phenomenon but also supports the development of mitigation and control actions.

As an exploratory study within a specific context, this research represents an initial approach for analyzing missed approaches due to runway occupancy in the Colombian operational environment, providing elements that may be considered in future research and operational decision-making processes.

Key Words: Missed Approach, Air Traffic Control, Aviation Safety, Regulatory Compliance.

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SECCIÓN 3

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BRIEFING DE
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3 WP del MOSA

El Working Paper, titulado Operational Safety Observation Programs in Military Aviation: A Framework for Implementation in the Colombian Aerospace Force, fue desarrollado por Harold J. Acosta León ¹, Erika Juliana Estrada Villa², MY. Francine Juliette Pineda Mongui³ como una contribución académica orientada al fortalecimiento de la gestión de la seguridad operacional en la Fuerza Aeroespacial Colombiana. Elaborado en idioma inglés con el propósito de ampliar su alcance y visibilidad internacional, el documento aborda la necesidad de incorporar herramientas proactivas y predictivas que complementen los mecanismos tradicionales de identificación de peligros y gestión del riesgo. La investigación parte del reconocimiento de que los Sistemas de Gestión de la Seguridad Operacional (SMS) requieren fuentes de información cada vez más robustas que permitan anticipar riesgos antes de que estos se materialicen en incidentes o accidentes, fortaleciendo así la capacidad organizacional para la toma de decisiones basadas en evidencia operacional.

OPERATIONAL SAFETY OBSERVATION PROGRAMS IN MILITARY AVIATION: A FRAMEWORK FOR IMPLEMENTATION IN THE COLOMBIAN AEROSPACE FORCE

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3.1 Introduction

Over the past decades, aviation safety has undergone a significant transformation driven by advances in technology, regulatory frameworks, operational procedures, and training methodologies. These developments have contributed to the consolidation of increasingly robust safety management practices across both civil and military aviation. As aviation systems continue to evolve in complexity, organizations are faced with the challenge of identifying and managing safety risks before they materialize into incidents or accidents. Consequently, contemporary safety management has progressively expanded beyond traditional reactive approaches, embracing proactive and predictive strategies aimed at understanding operational performance and strengthening risk management capabilities (ICAO, 2018; ICAO, 2022).

Traditional sources of safety information, including occurrence reporting systems, accident investigations, incident analyses, and flight data monitoring programs, continue to play a fundamental role in supporting organizational learning and safety improvement. However, many of these mechanisms primarily generate information after a deviation, event, or operational occurrence has taken place. While these processes remain essential components of a mature Safety Management System (SMS), they may not fully capture the operational realities, adaptations, and performance variations that characterize routine aviation activities. For this reason, aviation organizations increasingly recognize the value of complementing existing safety information sources with methodologies capable of

examining operational performance as it naturally occurs during normal operations (ICAO, 2018; ICAO, 2022).

Operational observation programs have emerged as an important mechanism for acquiring safety information directly from routine operations. These programs enable trained observers to systematically collect information regarding operational complexity, environmental conditions, human performance, procedural compliance, threats, errors, and organizational influences. Unlike traditional auditing or inspection activities, operational observation programs seek to understand how operational personnel successfully manage everyday challenges while maintaining acceptable levels of safety performance. By focusing on normal operations rather than exclusively on adverse outcomes, these programs provide valuable insights into both organizational strengths and areas requiring improvement, supporting evidence-based decision-making and continuous safety enhancement (FAA, 2017; ICAO, 2002).

Among the most widely recognized operational observation methodologies in aviation is the Line Operations Safety Audit (LOSA), a structured observational approach designed to collect safety-related information during normal flight operations. LOSA introduced a systematic framework for understanding operational performance through the identification and analysis of threats, errors, and undesired states encountered during routine activities. This methodology contributed significantly to the practical application of the Threat and Error Management (TEM) framework, which has become one of the most influential models for understanding the interaction between human performance and safety within complex operational environments. Together, LOSA and TEM have demonstrated the value of direct operational observation as a proactive source of safety information capable of complementing traditional safety management processes (FAA, 2017; ICAO, 2002; SKYbrary Aviation Safety, 2023).

Within military aviation environments, the implementation of operational observation programs presents unique opportunities and challenges. Military organizations routinely operate under dynamic conditions characterized by diverse mission requirements, complex operational environments, elevated levels of uncertainty, and demanding organizational interactions. These characteristics reinforce the importance of obtaining reliable operational information capable of supporting risk management activities, organizational learning processes, and continuous improvement initiatives. Although Safety Management Systems have become increasingly established within military aviation organizations, operational observation programs represent an additional opportunity to strengthen existing safety management processes through the systematic collection and analysis of operational information (ICAO, 2018; ICAO, 2022).

The Colombian Aerospace Force has strengthened its safety management capabilities through the implementation of the Manual de Gestión de la Seguridad Operacional (MAGSO), which constitutes the institutional framework of its Safety Management System. Through this framework, the organization promotes the systematic identification of hazards, the management of operational risks, safety assurance activities, and the continuous improvement of safety performance. Nevertheless, the increasing emphasis on proactive and predictive safety management highlights the need to explore complementary mechanisms capable of capturing operational information directly from routine activities. In this context, the implementation of an operational safety observation program represents an opportunity to enhance organizational learning, strengthen risk management processes, and improve the identification of operational threats, errors, and latent conditions before they contribute to adverse outcomes (Fuerza Aeroespacial Colombiana, 2025; ICAO, 2018).

This Working Paper examines the conceptual foundations, operational principles, and implementation considerations associated with operational safety observation programs in military aviation. Drawing upon internationally recognized safety concepts, including Safety Management Systems, Threat and Error Management, and the principles derived from Line Operations Safety Audits, the document proposes a framework to support the future implementation of the Military Operational Safety Audit (MOSA) program within the Colombian Aerospace Force. Rather than replicating existing civil aviation methodologies, the purpose of this paper is to identify the essential elements that may guide the development of a military-oriented observation program capable of generating meaningful safety information.

3.2 Evolution of Safety Data Collection in Aviation

The continuous improvement of aviation safety has been closely associated with the ability of organizations to collect, analyze, and learn from safety-related information. Throughout the evolution of safety management, aviation organizations have progressively expanded the range of tools and methodologies used to identify hazards, assess risks, and support decision-making processes. As operational environments became increasingly complex, traditional approaches based solely on the investigation of accidents and incidents proved insufficient to provide a comprehensive understanding of operational performance and emerging safety challenges (ICAO, 2018; ICAO, 2022).

This evolution has led to the development of complementary approaches to safety data collection, ranging from reactive mechanisms focused on adverse events to proactive and predictive strategies designed to identify safety risks before they result in operational

consequences. Within this progression, operational observation programs emerged as an additional source of safety information capable of capturing operational realities during normal activities, providing organizations with valuable insights that are often unavailable through conventional reporting and investigative systems. Understanding this evolution is essential for establishing the context in which operational observation programs such as the Military Operational Safety Audit (MOSA) can contribute to the continuous improvement of safety performance within the Colombian Aerospace Force.

3.2.1 Reactive Approaches

Historically, aviation safety management was largely based on reactive approaches that relied on the investigation and analysis of accidents, serious incidents, and operational occurrences after they had already taken place. Under this perspective, safety improvements were primarily driven by lessons learned from adverse events, allowing organizations to identify causal factors, implement corrective actions, and prevent the recurrence of similar situations. As a result, accident investigation processes became one of the principal sources of safety information and played a fundamental role in the development of modern aviation safety practices (ICAO, 2018; ICAO, 2022).

Reactive approaches continue to represent an essential component of contemporary Safety Management Systems because they provide valuable information regarding system failures, operational deficiencies, human performance issues, organizational weaknesses, and risk controls that may not have functioned as intended. Occurrence reporting systems, accident investigations, incident analyses, and voluntary reporting mechanisms remain important tools for identifying hazards and supporting continuous improvement efforts. These mechanisms enable organizations to understand what happened, why it happened, and what measures may be required to reduce the likelihood of similar events occurring in the future (ICAO, 2018; EUROPEAN UNION, 2014).

Despite their importance, reactive approaches possess inherent limitations. By definition, they depend on the occurrence of an undesired event before meaningful safety information can be generated. Consequently, organizations may obtain critical safety insights only after operational consequences have already materialized. Furthermore, reactive systems often provide limited visibility into the everyday adaptations, operational challenges, and successful performance adjustments that characterize normal operations. While reactive approaches remain indispensable for understanding safety outcomes and supporting organizational learning, the need to identify hazards and manage risks before adverse events occur ultimately contributed to the development of more proactive approaches to safety management (ICAO, 2018; ICAO, 2022).

3.2.2 Proactive Approaches

The limitations associated with reactive safety management led aviation organizations to adopt more proactive approaches aimed at identifying hazards and managing risks before they resulted in incidents or accidents. Rather than relying exclusively on information derived from adverse events, proactive approaches seek to collect safety-related information from routine operations, operational assessments, risk analyses, safety reports, audits, inspections, and other mechanisms capable of identifying emerging threats and vulnerabilities before operational consequences occur. This evolution represented a significant shift in safety thinking, moving from learning solely from failures to actively searching for conditions that could potentially affect operational performance and safety outcomes (ICAO, 2018; ICAO, 2022).

Within a proactive safety framework, organizations continuously monitor their operational environment to identify hazards, assess risk levels, evaluate the effectiveness of existing controls, and implement preventive actions when necessary. Safety management activities are therefore not limited to responding to occurrences but also focus on understanding operational conditions, organizational influences, and human performance factors that may contribute to future safety risks. This approach supports more informed decision-making and enables organizations to address potential safety concerns before they escalate into operational events (ICAO, 2018).

The implementation of Safety Management Systems further reinforced the importance of proactive safety management by promoting systematic processes for hazard identification, risk assessment, safety assurance, and continuous improvement. Through these processes, organizations are encouraged to use multiple sources of information to develop a more comprehensive understanding of operational performance. As a result, proactive safety management has become a fundamental element of contemporary aviation safety, providing a structured framework for identifying and mitigating risks before they affect operational activities (ICAO, 2018; ICAO, 2022).

Among the various tools that support proactive safety management, operational observation programs have gained increasing recognition due to their ability to capture information directly from normal operations. By observing operational activities as they occur, these programs provide organizations with valuable insights regarding threats, errors, operational challenges, procedural compliance, and human performance. Consequently, operational observation methodologies have become an important complement to traditional safety data sources, contributing to a broader and more comprehensive understanding of operational safety (FAA, 2017; ICAO, 2002).

3.2.3 Predictive Approaches

The continued evolution of aviation safety management has led organizations to move beyond reactive and proactive practices toward predictive approaches that seek to anticipate potential safety issues before they emerge within operational environments. Predictive safety management is based on the systematic collection, integration, and analysis of operational data to identify trends, patterns, and indicators that may signal increasing levels of risk. Rather than focusing solely on past events or current operational conditions, predictive approaches aim to support informed decision-making by providing organizations with an enhanced understanding of future safety challenges and emerging operational vulnerabilities (ICAO, 2018; ICAO, 2022).

Advances in safety data collection, reporting systems, and information management processes have significantly expanded the ability of aviation organizations to identify subtle changes in operational performance. By analyzing information from multiple sources, organizations can detect recurring patterns, monitor the effectiveness of safety controls, and identify areas requiring additional attention before adverse consequences occur. This capability has become increasingly important as aviation systems continue to grow in complexity and generate larger volumes of operational information (ICAO, 2018; EUROCONTROL, 2022)

Predictive approaches are closely associated with the development of data-driven safety management practices. These practices rely on the continuous monitoring of safety indicators, trend analysis, safety performance measurement, and the systematic evaluation of operational information to identify potential areas of concern. As a result, organizations can prioritize resources, strengthen risk controls, and implement preventive actions based on evidence derived from operational data rather than waiting for the occurrence of safety events (ICAO, 2018; EUROCONTROL 2022).

Although predictive safety management increasingly relies on the availability and analysis of operational information, its effectiveness ultimately depends on the quality, reliability, and diversity of the data available to the organization. Consequently, modern safety management systems benefit from integrating multiple sources of safety information, including occurrence reporting systems, flight data monitoring programs, audits, inspections, safety assessments, and operational observation initiatives. Together, these complementary sources contribute to a more comprehensive understanding of operational performance and support a more resilient approach to safety management (ICAO, 2018; ICAO, 2022).

Within this context, operational observation programs provide an additional layer of information that can enhance predictive safety capabilities by identifying operational conditions, human performance factors, and organizational influences that may not be fully captured through traditional reporting or automated monitoring systems. The integration of

observational data with other safety information sources offers organizations an opportunity to strengthen their ability to anticipate risks and support continuous safety improvement across complex operational environments.

3.2.4 The Role of Operational Observation Programs

The evolution of aviation safety management has progressively expanded the range of information sources available to organizations for identifying hazards, assessing risks, and supporting safety-related decision-making. While occurrence reporting systems, accident investigations, audits, inspections, and flight data monitoring programs continue to provide valuable safety information, these mechanisms may not always capture the full complexity of operational performance during routine activities. As a result, aviation organizations have increasingly recognized the importance of obtaining information directly from normal operations in order to better understand how safety is maintained under everyday operational conditions (ICAO, 2018; ICAO, 2022).

Operational observation programs were developed to address this need by providing a structured mechanism for collecting information from routine operations. Through the systematic observation of operational activities, organizations can obtain valuable insights regarding environmental conditions, operational challenges, procedural application, human performance, communication practices, workload management, and other factors that influence safety outcomes. Unlike traditional approaches that primarily focus on events that have already occurred, operational observation allows organizations to examine operational performance as it naturally unfolds within the operational environment (FAA, 2017; ICAO, 2018).

A key characteristic of operational observation programs is their focus on understanding both successful performance and operational vulnerabilities. Rather than concentrating exclusively on errors or failures, these programs seek to identify how personnel adapt to operational demands, manage threats, and maintain safety margins under varying conditions. This perspective aligns with contemporary safety management principles, which recognize that safety is not only reflected by the absence of accidents, but also by the organization's ability to consistently manage operational complexity and sustain effective performance during routine activities (ICAO, 2018; SKYbrary Aviation Safety, 2023).

The information generated through operational observation programs can significantly strengthen safety management activities by complementing existing safety data sources. When integrated within a Safety Management System, observational data can support hazard identification processes, improve risk assessments, contribute to safety assurance activities, and facilitate evidence-based decision-making. Furthermore, operational observation can provide a deeper understanding of the interactions between

operational procedures, environmental conditions, organizational factors, and human performance, allowing organizations to identify opportunities for continuous improvement before adverse events occur (ICAO, 2018; ICAO, 2022).

For military aviation organizations, operational observation programs offer an opportunity to enhance existing safety management processes through the direct collection of operational information during routine activities. Within the Colombian Aerospace Force, the principles of operational observation are consistent with the proactive and predictive objectives established by the Manual de Gestión de la Seguridad Operacional (MAGSO). Consequently, operational observation represents a valuable source of safety information capable of supporting organizational learning, strengthening risk management processes, and contributing to the continuous improvement of operational safety performance (Fuerza Aeroespacial Colombiana, 2025).

3.3 Operational Observation Programs in Aviation

As aviation organizations have progressively adopted proactive and predictive safety management approaches, operational observation programs have become an increasingly valuable source of safety information. Unlike traditional safety data collection methods that depend primarily on reported occurrences, investigations, or operational deviations, operational observation enables organizations to obtain direct insight into how personnel perform their duties during normal operations. Through structured observation processes, organizations can better understand operational complexity, human performance, threat management practices, procedural compliance, and the factors that contribute to both successful and unsuccessful operational outcomes.

Over the past decades, operational observation methodologies have evolved into recognized safety management tools capable of supporting hazard identification, risk assessment, organizational learning, and continuous safety improvement. Among these methodologies, the Line Operations Safety Audit (LOSA) has emerged as the most widely recognized international reference model, providing the foundation for the development of observation-based safety programs across different aviation environments. At the same time, the Threat and Error Management (TEM) framework has become the principal analytical model used to interpret observational data and understand the interaction between threats, errors, operational defenses, and safety outcomes.

This chapter examines the role of operational observation as a source of safety information, reviews LOSA as the international benchmark for structured operational observation programs, analyzes the contribution of the Threat and Error Management framework, and summarizes the principal lessons learned from the implementation of

operational observation programs within the aviation industry. These concepts provide the theoretical and methodological foundation for the development of the Military Operational Safety Audit (MOSA) framework proposed for the Colombian Aerospace Force

3.3.1 Operational Observation as a Source of Safety Information

The effectiveness of any Safety Management System depends largely on the quality, reliability, and diversity of the information available to support decision-making processes. Aviation organizations traditionally obtain safety-related information through occurrence reporting systems, accident investigations, audits, inspections, and flight data monitoring programs. While these mechanisms provide valuable insights into safety performance, they may not fully capture the operational realities, human interactions, and contextual factors that influence everyday operations. Consequently, operational observation has emerged as an important complementary source of safety information capable of providing direct insight into how operations are conducted under normal conditions (ICAO, 2018; ICAO, 2022).

Operational observation is based on the systematic collection of information through the direct observation of personnel performing their operational duties in real-world environments. Unlike inspections, evaluations, or compliance audits, operational observation seeks to understand operational performance as it naturally occurs without introducing artificial conditions or unnecessary interference with ongoing activities. This approach enables organizations to identify operational challenges, environmental influences, procedural adaptations, communication practices, workload management strategies, and other factors that may influence safety performance but are not always visible through traditional reporting systems (FAA, 2017).

One of the principal strengths of operational observation lies in its ability to provide contextual information regarding human performance. Aviation operations are conducted within complex and dynamic environments where personnel must continuously adapt to changing conditions, operational demands, and unforeseen circumstances. Through direct observation, organizations can better understand how operational personnel recognize threats, manage risks, apply procedures, communicate with other team members, and maintain safety margins during routine activities. This information contributes to a more comprehensive understanding of operational performance and organizational resilience (SKYbrary Aviation Safety, 2023; ICAO, 2018).

Operational observation also supports a broader perspective of safety by focusing not only on failures or deviations, but also on successful performance. Observers can identify practices, behaviors, and operational strategies that contribute positively to safety outcomes,

allowing organizations to understand how safety is achieved on a daily basis. This perspective complements traditional safety information sources by highlighting both vulnerabilities and strengths within the operational system, thereby supporting more balanced and evidence-based safety management decisions (ICAO, 2018).

As aviation organizations continue to strengthen proactive and predictive safety management capabilities, operational observation has become increasingly recognized as a valuable source of safety information. When integrated within an established Safety Management System, observational data can enhance hazard identification, improve risk assessments, support safety assurance activities, and contribute to continuous organizational learning. For these reasons, operational observation programs have become an important component of contemporary aviation safety management and a key foundation for the development of structured methodologies such as the Line Operations Safety Audit (LOSA) and its subsequent adaptations to different operational environments (FAA, 2017; ICAO, 2022).

3.3.2 LOSA as an International Reference Model

The Line Operations Safety Audit (LOSA) is widely recognized as the international benchmark for operational observation programs in aviation. Developed for civil and commercial aviation, LOSA introduced a structured methodology for collecting safety-related information through the direct observation of normal flight operations. Its primary objective is to identify threats, errors, and undesired operational states that may influence safety performance, allowing organizations to obtain proactive safety information beyond that provided by traditional occurrence reporting systems and accident investigations (FAA, 2017).

The success of LOSA is largely attributable to its standardized observation methodology, non-punitive philosophy, confidentiality principles, and integration with the Threat and Error Management (TEM) framework. Through trained observers and systematic data collection processes, LOSA enables organizations to better understand operational performance, identify recurring safety concerns, and support evidence-based decision-making. As a result, LOSA has become one of the most widely adopted operational observation methodologies within the aviation industry and serves as an important reference for the development of similar programs in other operational domains (ICAO, 2018; FAA, 2017).

Although LOSA provides a valuable foundation for operational observation, important differences exist between the operational environments of civil aviation and military aviation. While LOSA was designed primarily for airline operations conducted under relatively standardized conditions, military aviation encompasses a broader range of activities, including training missions, transport operations, tactical missions, operational deployments, and other activities that may involve higher levels of uncertainty, operational variability, and mission-specific requirements. These differences influence not only the operational context in which observations are conducted, but also the objectives, scope, and application of the observation program itself.

As presented in Table 1, both LOSA and the proposed Military Operational Safety Audit (MOSA) program share several fundamental principles as both methodologies rely on structured observation processes, trained observers, standardized data collection procedures, and the systematic analysis of operational information to support safety management activities. Similarly, both approaches seek to generate proactive safety information capable of improving organizational learning, supporting risk management processes, and enhancing operational safety performance.

Table 1. Comparison Between LOSA and MOSA Operational Observation Programs

Characteristic	MOSA (Military Operational Safety Audit)	LOSA (Line Operations Safety Audit)
Audit Type	Structured operational observation program adapted to military aviation environments	Structured operational observation program conducted during normal flight operations
Operational Scope	Military aviation, including training, transport, tactical, and operational missions	Civil and commercial aviation flight operations
Primary Objective	Identify operational threats, errors, and safety vulnerabilities within military operations to support risk management and safety improvement	Identify threats, errors, and undesired states during normal flight operations to improve safety performance
Data Collection Method	Direct operational observation supported by standardized observation forms, operational classification systems, and military safety processes	Direct observation of flight crews during normal operations using standardized LOSA observation methodologies
Safety Focus	Operational safety performance within military environments, considering mission requirements, organizational factors, and operational risks	Threat and Error Management (TEM) during normal airline operations

Relationship with Safety Systems	Integrated with the Military Safety Management System (MAGSO) and other military safety information sources	Integrated with Safety Management Systems (SMS), FOQA, reporting systems, and other airline safety programs
Observer Profile	Trained military observers with operational and methodological expertise in military aviation activities	Specially trained LOSA observers with operational knowledge of airline flight operations
Operational Environment	Military organizations operating under diverse mission profiles and operational conditions	Civil and commercial airline operations conducted under routine flight conditions
Expected Outputs	Operational observations, threat identification, error classification, safety trends, and recommendations for military risk management	Threat and error data, operational trends, and recommendations to improve flight safety performance

Note. Developed by the authors based on ICAO (2018), FAA (2017), and Fuerza Aeroespacial Colombiana (2025).

However, significant differences can also be identified as LOSA focuses primarily on commercial flight operations and emphasizes the identification and management of threats and errors during normal airline activities, while MOSA is intended to support military aviation organizations and therefore considers a wider range of operational contexts, including training, transport, tactical, and operational missions. MOSA also seeks to integrate operational observation within the safety management framework established by the Manual de Gestión de la Seguridad Operacional (MAGSO), ensuring that observational data contributes directly to military risk management processes, operational decision-making, and continuous safety improvement within the Colombian Aerospace Force.

Furthermore, while LOSA is commonly integrated with airline safety programs such as Flight Operations Quality Assurance (FOQA) and other civil aviation safety information systems, MOSA is envisioned as part of a broader military safety ecosystem that may incorporate information from operational reports, safety investigations, flight data analysis programs, and other military safety management processes. Consequently, LOSA should be viewed as the conceptual and methodological foundation upon which MOSA can be developed, while recognizing the adaptations required to address the operational, organizational, and mission-specific characteristics of military aviation.

3.3.3 Threat and Error Management (TEM)

Threat and Error Management (TEM) is a conceptual framework developed to understand the relationship between human performance and operational safety within complex aviation environments. The model recognizes that threats, errors, and operational deviations are an inherent part of aviation activities and that safety is achieved through the

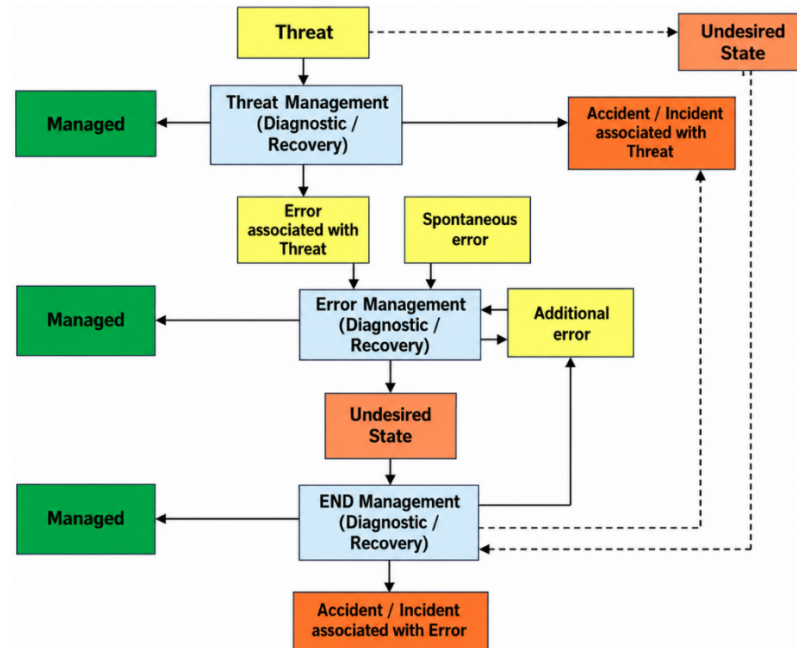
effective management of these factors rather than through their complete elimination. Consequently, TEM provides a systematic approach for identifying, assessing, and mitigating operational risks before they evolve into incidents or accidents, making it one of the most influential frameworks within contemporary aviation safety management (ICAO, 2018; SKYbrary Aviation Safety, 2023).

The origins of TEM are closely associated with the development of the Line Operations Safety Audit (LOSA). As operational observation programs expanded within the aviation industry, organizations required a structured method to classify and analyze the information collected during normal operations. TEM emerged as the framework capable of explaining how operational personnel interact with threats, commit and manage errors, and recover from undesired operational situations. As a result, TEM became a fundamental component of LOSA and later evolved into a widely adopted safety management framework applicable across different aviation domains (FAA, 2017).

The TEM framework is built around three fundamental elements: threats, errors, and undesired states. Threats are events or conditions that originate outside the direct influence of operational personnel and have the potential to increase operational complexity or reduce safety margins. Examples include adverse weather conditions, air traffic congestion, equipment malfunctions, organizational pressures, operational constraints, or mission-specific challenges. Errors correspond to actions or decisions that deviate from intended procedures or operational expectations, whereas undesired states represent situations in which safety margins have been reduced and corrective action is required to prevent escalation toward an incident or accident (ICAO, 2018).

Figure 1 illustrates the fundamental logic of the TEM model and the relationship between its principal components. The figure shows how threats may be successfully managed before generating errors, how errors can be detected and recovered before creating undesired states, and how undesired states can be corrected before leading to incidents or accidents. The model also highlights that recovery opportunities exist at multiple stages of the operational process, reinforcing the concept that safety is achieved through the continuous management of operational conditions rather than through the absence of threats or errors. This perspective provides organizations with a practical framework for understanding operational performance and identifying opportunities for safety improvement (Dirección General de Aeronáutica Civil de Chile, 2015).

Figure 1. Relationship Between Threats, Errors, Undesired States, and Recovery Actions



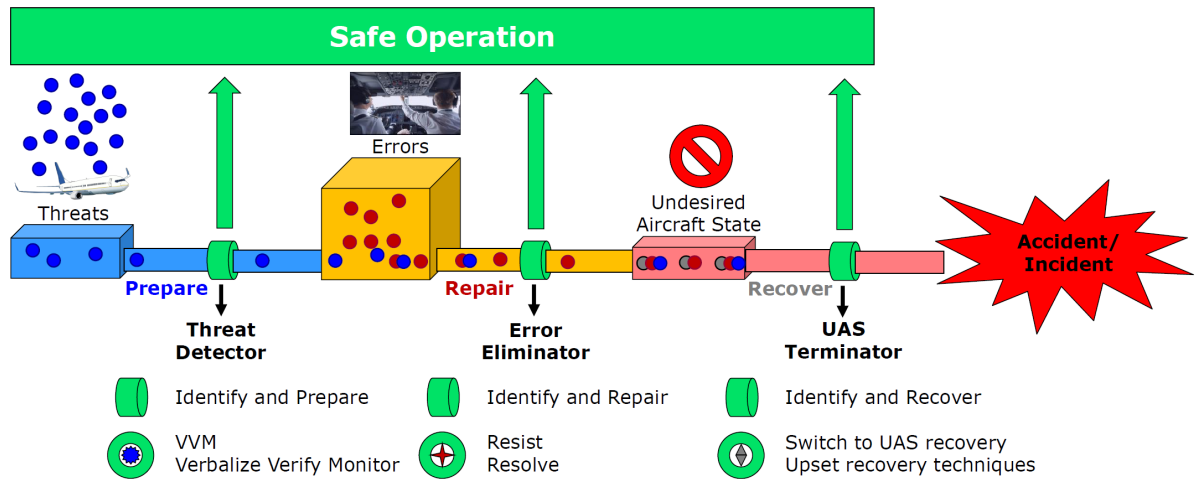
Note. Adapted from Crew Resource Management (CRM) & Threat and Error Management (TEM), Dirección General de Aeronáutica Civil de Chile, Departamento Prevención de Accidentes, July 2015, p. 22. The figure illustrates the relationship between threats, errors, undesired states, recovery actions, and the potential progression toward incidents or accidents.

The TEM framework also recognizes that effective safety performance depends on the ability of operational personnel to identify, manage, and recover from operational challenges. Consequently, threats and errors are not viewed solely as precursors to failure, but also as opportunities to evaluate the effectiveness of operational defenses and recovery strategies. This perspective shifts the focus from accident causation toward the understanding of how safe operations are successfully maintained despite the continuous presence of operational threats and human errors (SKYbrary Aviation Safety, 2023; ICAO, 2022).

Figure 2 presents the operational application of TEM through the Luxair model, which emphasizes three sequential safety barriers: Prepare, Repair, and Recover. The first barrier focuses on identifying and preparing for threats before they affect the operation. The second barrier is oriented toward the detection and correction of errors once they occur. The final barrier addresses the identification and recovery of undesired states before they escalate into incidents or accidents. This representation highlights the dynamic nature of TEM and demonstrates how operational personnel continuously apply defensive strategies to maintain safe operations despite the presence of threats and errors.

Figure 2. Threat and Error Management Operational Concept

Luxair TEM Concept



Note. Adapted from *TEM Machine Explanatory Text*, Aircraft Owners and Pilots Association Luxembourg (AOPA Luxembourg). The figure illustrates the operational flow of threats, errors, undesired aircraft states, and the defensive barriers of preparation, error correction, and recovery used to maintain safe operations.

One of the principal strengths of TEM is its ability to provide a practical structure for analyzing operational performance during normal activities. Rather than focusing exclusively on failures or accidents, TEM facilitates the systematic identification of operational threats, human errors, successful recovery actions, and organizational defenses. This perspective supports proactive and predictive safety management by enabling organizations to understand not only where vulnerabilities exist, but also how operational personnel successfully maintain safety under routine operational conditions (FAA, 2017; ICAO, 2022).

For operational observation programs such as LOSA and the proposed Military Operational Safety Audit (MOSA), TEM provides the analytical foundation through which observational data can be classified, interpreted, and transformed into meaningful safety information. By identifying threats, errors, recovery actions, and undesired states during normal operations, organizations can obtain a deeper understanding of operational performance, strengthen hazard identification processes, improve risk management activities, and support continuous safety improvement. Consequently, TEM represents a critical component of the conceptual framework supporting the implementation of MOSA within the Colombian Aerospace Force (FAA, 2017; ICAO, 2018).

3.3.4 Lessons Learned from Operational Observation Programs

The implementation of operational observation programs throughout the aviation industry has generated valuable lessons regarding the collection, interpretation, and application of safety information obtained during normal operations. One of the earliest and

most influential experiences emerged when airlines began implementing structured observation programs to better understand how flight crews applied Crew Resource Management (CRM) principles during routine operations. These initiatives demonstrated that traditional training evaluations and simulator assessments were often insufficient to fully understand operational performance in real-world environments. Direct observation of line operations provided a more accurate representation of crew behavior, communication, workload management, leadership, decision-making processes, and operational adaptations during normal flights (ICAO, 2002).

A second lesson concerns the critical importance of confidentiality, trust, and voluntary participation. Early LOSA implementations revealed that operational personnel could perceive observation activities as performance evaluations rather than safety improvement initiatives. To address these concerns, organizations implementing LOSA established strict confidentiality procedures, emphasizing that observations would not be used for disciplinary purposes and that collected information would remain anonymous. Experience demonstrated that trust is a fundamental prerequisite for obtaining reliable observational data and ensuring the acceptance of the program by operational personnel. As a result, confidentiality and non-punitive participation became core principles of LOSA implementation (ICAO, 2002).

Another important lesson emerged from the evolution of LOSA itself. While the methodology was initially developed to observe operational performance and CRM-related behaviors, its application demonstrated the need for a structured framework capable of explaining how operational personnel manage threats and errors during routine activities. This experience contributed directly to the consolidation of the Threat and Error Management (TEM) framework, which provides a systematic approach for understanding the relationship between threats, errors, undesired states, and operational outcomes. The integration of LOSA and TEM significantly expanded the analytical value of operational observation programs and strengthened their contribution to proactive safety management (ICAO, 2002; ICAO, 2018).

Operational observation programs have also demonstrated their ability to support measurable organizational improvements. Information obtained through LOSA observations has been used to identify operational vulnerabilities, improve training programs, strengthen standard operating procedures, enhance crew coordination, and support risk mitigation initiatives. Furthermore, repeated observation cycles have allowed organizations to evaluate the effectiveness of corrective actions and monitor safety performance improvements over time. These experiences confirmed that operational observation programs can serve not only as diagnostic tools but also as mechanisms for supporting continuous safety improvement (ICAO, 2002; FAA, 2017).

The expansion of LOSA principles beyond flight operations generated additional lessons regarding the adaptability of operational observation methodologies. Over time, observation programs were extended to maintenance activities, ramp operations, and ground handling environments. These initiatives demonstrated that structured observation principles could successfully generate meaningful safety information across multiple operational domains where human performance plays a critical role in safety outcomes. The resulting observations contributed to improvements in operational procedures, organizational coordination, and risk management practices, further demonstrating the versatility of operational observation methodologies (ICAO, 2002; FAA, 2017).

Perhaps the most significant lesson learned from operational observation programs is that safety information obtained during normal operations provides insights that cannot be derived exclusively from accidents, incidents, audits, or occurrence reports. Operational observation allows organizations to understand how safety is maintained on a daily basis, how personnel adapt to operational challenges, and how threats and errors are successfully managed before adverse consequences occur. This perspective aligns closely with modern proactive and predictive safety management principles and provides a strong foundation for the implementation of military-oriented observation methodologies such as the Military Operational Safety Audit (MOSA) program proposed for the Colombian Aerospace Force (ICAO, 2002; ICAO, 2018; ICAO, 2022).

3.4 MOSA Implementation Framework for the Colombian Aerospace Force

The successful implementation of an operational observation program requires more than the adoption of observation methodologies or data collection procedures. It demands the integration of organizational, operational, methodological, and cultural elements that ensure the program generates reliable, useful, and sustainable safety information over time. International experience derived from operational observation programs such as the Line Operations Safety Audit (LOSA) has demonstrated that the effectiveness of these initiatives depends on the establishment of a clearly defined framework that aligns observation activities with organizational safety objectives, operational realities, and Safety Management System (SMS) requirements. Consequently, the development of a Military Operational Safety Audit (MOSA) program within the Colombian Aerospace Force requires a structured implementation framework capable of integrating operational observation into existing safety management processes while addressing the specific characteristics of military aviation operations (ICAO, 2002; ICAO, 2018; FAA, 2017).

Building upon the principles of operational observation, Threat and Error Management (TEM), and the requirements established by the Manual de Gestión de la

Seguridad Operacional (MAGSO), this chapter presents the proposed implementation framework for MOSA within the Colombian Aerospace Force. The framework addresses the rationale for implementation, its alignment with the institutional Safety Management System, the profile and training requirements of MOSA observers, and the information protection principles necessary to support a Just Culture environment. Together, these elements provide the organizational and methodological foundation required to ensure that MOSA functions as a credible, standardized, and effective mechanism for strengthening proactive and predictive safety management across military aviation operations (Fuerza Aeroespacial Colombiana, 2025; ICAO, 2022).

3.4.1 Rationale for MOSA Implementation

The continuous evolution of aviation safety management has highlighted the importance of obtaining safety information from multiple complementary sources. While occurrence reporting systems, accident investigations, audits, inspections, and other safety monitoring activities remain essential components of modern Safety Management Systems (SMS), these mechanisms primarily generate information after a deviation, event, or safety concern has already occurred. Consequently, aviation organizations increasingly recognize the need to strengthen proactive and predictive safety management capabilities through methodologies capable of identifying operational threats, vulnerabilities, and emerging risks before they contribute to adverse outcomes (ICAO, 2018; ICAO, 2022).

Within the Colombian Aerospace Force, the Manual de Gestión de la Seguridad Operacional (MAGSO) establishes the institutional framework for managing operational safety through hazard identification, risk assessment, safety assurance activities, and continuous improvement processes. The effective implementation of these processes depends on the availability of reliable safety information capable of supporting evidence-based decision-making. Although existing safety information sources provide valuable insights into operational performance, they may not always capture the operational realities, human interactions, procedural adaptations, and contextual factors that characterize routine military aviation activities. As a result, opportunities may exist to strengthen the identification of operational hazards and safety vulnerabilities through the direct observation of normal operations (Fuerza Aeroespacial Colombiana, 2025; ICAO, 2018).

Operational observation programs have demonstrated their ability to provide valuable safety information by allowing organizations to observe how operational personnel manage threats, apply procedures, adapt to operational conditions, and maintain safety margins during routine activities. International experience obtained through LOSA has shown that structured observation programs can generate information that is often unavailable through traditional reporting systems, contributing to a more comprehensive

understanding of operational performance and supporting proactive safety management initiatives (ICAO, 2002; FAA, 2017).

The operational environment of military aviation presents additional challenges that reinforce the value of observational safety methodologies. Military organizations routinely conduct training, transport, tactical, and operational missions under varying environmental, organizational, and operational conditions. These activities frequently involve dynamic mission requirements, elevated operational complexity, and unique risk factors that may not be fully represented through conventional safety reporting mechanisms. Consequently, the implementation of an operational observation program specifically adapted to military aviation offers an opportunity to obtain a deeper understanding of operational performance and strengthen existing safety management capabilities.

For these reasons, the Military Operational Safety Audit (MOSA) is proposed as a structured operational observation program designed to complement existing safety information sources within the Colombian Aerospace Force. By integrating direct operational observation with the principles of Threat and Error Management (TEM) and the safety management processes established by the MAGSO, MOSA seeks to support hazard identification, improve risk management activities, strengthen safety assurance processes, and contribute to the continuous improvement of operational safety performance across military aviation operations (Fuerza Aeroespacial Colombiana, 2025; ICAO, 2018; ICAO, 2022).

3.4.2 Alignment with the MAGSO

The Military Operational Safety Audit (MOSA) is conceived as a complementary safety management tool designed to support and strengthen the operational safety framework established by the Manual de Gestión de la Seguridad Operacional (MAGSO) of the Colombian Aerospace Force. Rather than functioning as an independent safety program, MOSA is intended to generate operational safety information that directly contributes to the objectives, processes, and principles of the institutional Safety Management System (SMS). Through the systematic observation of normal military operations, MOSA provides an additional source of operational data capable of supporting evidence-based decision-making, enhancing operational awareness, and strengthening the organization's ability to identify and manage safety risks. As summarized in Table 2, MOSA contributes to multiple components of the MAGSO framework, supporting safety policy and objectives, hazard identification, safety risk management, safety assurance, safety performance monitoring, safety promotion, continuous improvement, and the principles of Just Culture and non-punitive safety management (Fuerza Aeroespacial Colombiana, 2025; ICAO, 2018).

As presented in Table 2, one of the most significant contributions of MOSA relates to hazard identification and safety risk management. The MAGSO establishes the need to continuously identify hazards, assess risks, and implement appropriate mitigation measures to maintain acceptable levels of safety performance. In this context, MOSA enables the direct observation of operational threats, human performance challenges, procedural deviations, and operational vulnerabilities that may not always be captured through occurrence reporting systems, investigations, or other traditional safety information sources. The information obtained through structured operational observations provides additional evidence to support risk assessments, prioritize safety actions, and strengthen proactive and predictive safety management activities across military aviation operations (ICAO, 2018; ICAO, 2022).

Table 2 also illustrates the contribution of MOSA to safety assurance and safety performance monitoring. Through the collection and analysis of observational data, MOSA provides continuous operational feedback regarding the effectiveness of safety controls, mitigation measures, and organizational defenses. Furthermore, the program generates both qualitative and quantitative information concerning threats, errors, undesired states, and operational recovery actions, allowing the organization to identify operational trends, monitor safety indicators, and detect emerging safety concerns. This capability strengthens the organization's ability to evaluate operational performance, verify the effectiveness of implemented controls, and support evidence-based safety decision-making processes (FAA, 2017; ICAO, 2022).

Another important area highlighted in Table 2 is the relationship between MOSA, safety promotion, and continuous improvement. The findings generated through operational observations can support training programs, safety briefings, lessons learned activities, awareness campaigns, and other safety promotion initiatives. At the same time, the systematic analysis of observational data provides valuable information for the development of corrective actions, preventive measures, and long-term safety improvement strategies. Through these contributions, MOSA supports organizational learning and reinforces the continuous improvement philosophy established within the MAGSO and modern Safety Management Systems (Fuerza Aeroespacial Colombiana, 2025; ICAO, 2018).

Finally, Table 2 emphasizes the alignment between MOSA and the principles of Just Culture and non-punitive safety management. Consistent with internationally recognized LOSA methodologies, MOSA is designed to operate under strict confidentiality, anonymity, and information protection principles. Operational observations are intended to support learning, risk management, and safety improvement rather than individual evaluation or disciplinary action. This approach encourages voluntary participation, increases trust among

operational personnel, improves the quality of safety information collected, and reinforces the institutional commitment to operational safety. Consequently, MOSA not only strengthens specific safety management processes within the MAGSO but also supports the development of a positive safety culture throughout the Colombian Aerospace Force (FAA, 2017; Fuerza Aeroespacial Colombiana, 2025; ICAO, 2022).

Table 2. Alignment Between MOSA and the MAGSO Safety Management Framework

MAGSO Component	MAGSO Purpose	MOSA Contribution	Expected Benefit
Safety Policy and Objectives	Establish the organizational framework, responsibilities, and strategic direction for operational safety management.	MOSA supports institutional safety objectives by generating operational safety information obtained directly from normal military operations.	Improved decision-making based on operational evidence and alignment with organizational safety goals.
Hazard Identification	Identify conditions, threats, and operational factors that may affect safety performance.	MOSA enables the direct observation of operational threats, human performance challenges, procedural deviations, and operational vulnerabilities during routine activities.	Earlier identification of hazards that may not be captured through occurrence reporting systems alone.
Safety Risk Management	Assess identified hazards and determine appropriate risk mitigation measures.	Observational data collected through MOSA provides additional information to support risk assessments and the prioritization of safety actions.	Enhanced risk analysis and improved allocation of safety resources.
Safety Assurance	Monitor operational performance and evaluate the effectiveness of safety controls and mitigation measures.	MOSA provides continuous operational feedback through structured observations and trend analysis.	Improved monitoring of safety performance and verification of implemented controls.
Safety Performance Monitoring	Measure safety indicators and identify emerging safety trends.	MOSA generates qualitative and quantitative information regarding threats, errors, undesired states, and operational defenses.	Improved understanding of operational trends and emerging safety concerns.
Safety Promotion	Strengthen organizational learning, communication, and safety awareness.	MOSA findings can be used to support training programs, safety briefings, lessons learned activities, and awareness campaigns.	Increased safety culture and operational learning throughout the organization.
Continuous Improvement	Promote the ongoing enhancement of safety management processes and operational performance.	MOSA provides actionable safety information that supports corrective actions, preventive measures, and organizational learning initiatives.	Continuous improvement of operational safety performance across military aviation activities.
Just Culture and Non-Punitive Reporting	Encourage personnel participation in safety activities without fear of punishment.	MOSA applies confidentiality, anonymity, and non-punitive observation principles derived from LOSA methodologies.	Increased trust, participation, and quality of operational safety information.

Note. Developed by the authors based on the Manual de Gestión de la Seguridad Operacional (MAGSO) (Fuerza Aeroespacial Colombiana, 2025), the ICAO Safety Management Manual (Doc 9859) (ICAO, 2018), Annex 19 (ICAO, 2022), and LOSA guidance contained in FAA AC 120-90A (FAA, 2017).

3.4.3 MOSA Observer Profile

The effectiveness of the Military Operational Safety Audit (MOSA) program depends significantly on the competence, credibility, and consistency of its observers. As

demonstrated by LOSA implementations and operational observation programs, the quality of the information collected is directly influenced by the observer's ability to understand operational activities, identify threats and errors, apply standardized observation criteria, and accurately document operational events. Consequently, the observer represents a critical element of the MOSA framework and serves as the primary interface between operational activities and the safety management process.

Table 3 summarizes the proposed MOSA Observer Profile derived from internationally recognized operational observation principles. The profile combines operational knowledge, methodological expertise, ethical responsibilities, and data collection competencies necessary to conduct structured observations within military aviation environments. Observers are expected to possess operational experience, formal training in MOSA methodologies, proficiency in Threat and Error Management (TEM), and the ability to conduct observations without interfering with normal operations. At the same time, they must operate under strict confidentiality and non-punitive principles that support trust, voluntary participation, and the integrity of the information collection process.

In addition to technical competencies, MOSA observers must demonstrate professional judgment, objectivity, and analytical capability. Their role extends beyond the simple recording of operational events, requiring the interpretation of operational context, identification of contributing factors, recognition of successful recovery actions, and systematic documentation of safety-relevant information. For this reason, observer selection, training, standardization, and workload management constitute essential elements of the MOSA framework and directly influence the reliability and usefulness of the safety information generated through the program.

Table 3. MOSA Observer Profile

Profile Dimension	Observer Characteristic	Description
Operational Knowledge	Operational experience	Observers should possess direct operational experience in the environment being observed, allowing them to understand operational procedures, crew interactions, mission execution, and operational context.
	Understanding of operational environments	Observers must be capable of interpreting operational activities, procedures, communications, and mission dynamics within normal military aviation operations.
Technical and Methodological Expertise	Formal MOSA/LOSA training	Observers must receive standardized training in the MOSA methodology, observation procedures, data collection instruments, and Threat and Error Management (TEM) principles.
	Application of TEM	Observers must be capable of identifying threats, errors, undesired states, recovery actions, and operational defenses using a standardized analytical framework.
	Standardized data collection	Observers must apply standardized observation forms and common classification criteria to ensure consistency and reliability of collected information.

Operational Behaviour	Non-intrusive observation	Observers should act as “flies on the wall,” maintaining a discreet and non-threatening presence that does not alter normal operational behaviour.
	Observation during normal operations	Observations should be conducted during routine operational activities under normal conditions.
	Safety intervention authority	Although observers remain non-intrusive, they must recognize situations in which immediate intervention is necessary to prevent an unsafe condition.
Ethics and Trust	Confidentiality and anonymity	Observers are responsible for protecting the identity of personnel and ensuring that information is handled according to confidentiality requirements.
	Non-punitive philosophy	Observation data must be used exclusively for safety improvement purposes and not for disciplinary action or performance evaluation.
	Trust and professional credibility	Observers should be trusted by both the organization and operational personnel to ensure program acceptance and participation.
Observer Selection	Structured selection process	Observers should be selected through a formal process that considers operational expertise, credibility, objectivity, and organizational acceptance.
	Diversity of observer team	Observer teams should include personnel with diverse operational backgrounds and experiences to improve objectivity and analytical capability.
Data Quality and Standardization	Consistency in data recording	Observers must record information using common standards to ensure comparability and validity of results.
	Data quality responsibility	Observers constitute the primary source of operational information and therefore play a critical role in the quality and usefulness of the safety data collected.
Operational Limitations	Workload management	Observation assignments should be managed to avoid observer fatigue and maintain data quality.
	Detailed documentation capability	Observers must possess the analytical and documentation skills necessary to accurately record and describe operational observations.

Note. Developed by the authors based on FAA Advisory Circular 120-90A (FAA, 2017), Line Operations Safety Audit (LOSA) (ICAO, 2002).

3.4.4 Observer Training Requirements

The effectiveness, consistency, and credibility of the Military Operational Safety Audit (MOSA) program depend largely on the quality of observer training. Operational observation is a specialized activity that requires observers to possess not only operational experience, but also a standardized understanding of observation methodologies, data collection procedures, Threat and Error Management (TEM) principles, ethical requirements, and information protection measures. Without a structured training process, observers may interpret events differently, classify threats and errors inconsistently, or unintentionally influence the operation being observed. Consequently, MOSA observers must complete a formal training program designed to ensure methodological standardization, observational reliability, and data quality across all observation activities. The training program should combine theoretical instruction, practical exercises, simulated observations, calibration activities, and competency assessments to ensure that all observers apply the same criteria

when collecting and analyzing operational information. The MOSA observer training program should include, at a minimum, the following areas:

- a) **Safety Management System (SMS) and MAGSO Fundamentals:** Observers must understand the principles of operational safety management, the structure of the Safety Management System (SMS), and the role of the Manual de Gestión de la Seguridad Operacional (MAGSO) within the Colombian Aerospace Force. This training should explain how MOSA supports hazard identification, risk management, safety assurance, safety promotion, and continuous improvement activities.
- b) **MOSA Philosophy, Objectives, and Methodology:** Observers must understand the purpose of MOSA, its operational scope, expected outcomes, observation procedures, and methodological principles. Particular emphasis should be placed on the distinction between operational observation, performance evaluation, inspections, audits, and investigations.
- c) **Threat and Error Management (TEM):** Observers must receive formal instruction on the TEM framework, including the identification, classification, and analysis of threats, errors, undesired states, recovery actions, and operational defenses. This component provides the analytical foundation used to interpret operational observations and transform them into meaningful safety information.
- d) **Operational Observation Techniques:** Training should provide observers with the skills required to conduct structured observations during normal operations. This includes observation planning, information gathering, situational awareness, behavioral observation techniques, identification of operational cues, and methods for documenting operational events accurately and objectively.
- e) **Non-Intrusive Observation Principles ("Fly on the Wall"):** Observers must be trained to maintain a discreet and non-interfering presence throughout the observation process. This training should emphasize the importance of avoiding any influence on operational personnel, decision-making processes, crew behavior, or mission execution, while also defining the limited circumstances under which intervention may be necessary to prevent an immediate safety hazard.
- f) **Use of MOSA Data Collection Instruments:** Observers must be trained in the standardized use of MOSA observation forms, data collection tools, coding systems, operational classifications, and reporting formats. Standardization in the use of these instruments is essential to ensure consistency and comparability of data across different observers and operational environments.

- g) **Threat, Error, and Undesired State Classification:** Training should provide detailed guidance on the classification criteria used within MOSA, including operational threats, environmental threats, organizational influences, human performance issues, operational errors, procedural deviations, undesired states, and recovery actions. Practical exercises should be used to improve classification consistency among observers.
- h) **Operational Narrative Writing and Documentation:** Observers must be capable of producing clear, objective, factual, and technically accurate narratives describing observed events. Training should address the distinction between factual observations and personal interpretations, emphasizing chronological documentation and traceability of information.
- i) **Confidentiality, Information Protection, and Data Management:** Observers must understand the confidentiality requirements associated with operational observation programs, including data protection measures, anonymization procedures, information handling protocols, and limitations regarding the use and dissemination of collected information.
- j) **Just Culture and Non-Punitive Principles:** Training must reinforce the principles of Just Culture and the non-punitive philosophy that underpins MOSA. Observers should understand that the program is intended to support organizational learning and safety improvement rather than individual evaluation or disciplinary action.
- k) **Observer Ethics and Professional Conduct:** Observers must demonstrate impartiality, objectivity, professionalism, integrity, and respect for operational personnel. This component should establish the ethical standards expected throughout the observation process and the management of collected information.
- l) **Practical Observation Exercises and Calibration Activities:** Training should include practical observation sessions using operational scenarios, simulator sessions, video-based exercises, and case studies. Calibration activities should be conducted to ensure that all observers apply observation criteria, TEM classifications, and recording standards consistently.
- m) **Observer Qualification and Competency Assessment:** Prior to conducting operational observations, observers should successfully complete a formal competency assessment process. This assessment should evaluate theoretical knowledge, practical observation skills, TEM application, classification accuracy, data recording quality, and adherence to MOSA principles and procedures.

3.4.5 Information Protection and Just Culture

The long-term success of the Military Operational Safety Audit (MOSA) program depends not only on the quality of its methodology and the competence of its observers, but also on the confidence that operational personnel place in the program itself. Experience derived from operational observation methodologies and modern Safety Management Systems demonstrates that personnel are more willing to participate openly and behave naturally during observations when they trust that the information collected will be used exclusively to improve operational safety rather than for disciplinary action, performance evaluation, or individual accountability. Consequently, information protection and Just Culture principles constitute essential pillars of the MOSA framework and are fundamental to ensuring the reliability, credibility, and long-term effectiveness of the program (FAA, 2017; ICAO, 2022).

Information protection within MOSA is founded on the principle that observational data are collected to strengthen organizational safety performance rather than to assess individual performance. For this reason, all information obtained during observations should be managed through strict confidentiality procedures designed to protect personnel identities, preserve data integrity, and prevent the inappropriate use of information. Observation records should be de-identified whenever possible, access should be restricted to authorized personnel, and the information should be used exclusively for safety analysis, risk management, trend identification, and organizational learning activities. These safeguards are essential to maintaining trust and encouraging active participation across all military aviation environments (FAA, 2017; ICAO, 2022; Fuerza Aeroespacial Colombiana, 2025).

A critical component of information protection is the clear separation between safety information and disciplinary processes. Consistent with internationally recognized LOSA principles, MOSA observations are not intended to identify individual culpability, assign blame, or support punitive actions. Instead, the program seeks to understand how operational personnel manage threats, respond to operational challenges, apply procedures, and maintain safety margins during routine activities. By focusing on operational performance rather than individual blame, MOSA promotes a learning-oriented approach that encourages openness, transparency, and honest participation while generating safety information that can support organizational improvement (FAA, 2017; ICAO, 2002).

The application of Just Culture principles further strengthens this approach. Just Culture recognizes that human error is an inherent characteristic of complex operational systems and that most safety events result from a combination of organizational, operational, environmental, and human factors rather than from individual negligence alone. Consequently, personnel should feel confident reporting safety concerns, participating in

operational observations, and contributing safety information without fear of inappropriate punishment. At the same time, Just Culture does not eliminate accountability, as intentional violations, reckless conduct, or deliberate disregard for safety requirements remain subject to the corresponding organizational and disciplinary processes. The objective is to establish a balanced environment that promotes learning, reporting, and continuous improvement while preserving professional responsibility and operational discipline (ICAO, 2018; ICAO, 2022; Fuerza Aeroespacial Colombiana, 2025).

Ultimately, the protection of information and the application of Just Culture principles ensure that MOSA remains fully aligned with the objectives of the Manual de Gestión de la Seguridad Operacional (MAGSO) and with internationally recognized Safety Management System principles. Through confidentiality, anonymity, non-punitive participation, responsible information management, and a strong commitment to organizational learning, MOSA can generate high-quality operational safety information while simultaneously strengthening safety culture throughout the Colombian Aerospace Force. In this manner, information protection and Just Culture become not merely supporting elements of the program, but essential conditions for its successful implementation, institutional acceptance, and long-term sustainability (Fuerza Aeroespacial Colombiana, 2025; ICAO, 2018; ICAO, 2022).

3.5 Conclusions

The evolution of aviation safety management has progressively shifted organizational attention from reactive approaches focused on accidents and incidents toward proactive and predictive methodologies capable of identifying hazards and operational vulnerabilities before adverse events occur. Within this context, operational observation programs have emerged as valuable sources of safety information because they allow organizations to directly observe operational performance during normal activities and obtain insights that may not be captured through traditional reporting systems, investigations, audits, or inspections. The review of contemporary safety management principles demonstrates that operational observation complements existing safety information sources and strengthens an organization's ability to identify hazards, assess risks, and support continuous safety improvement (ICAO, 2018; ICAO, 2022).

The analysis of the Line Operations Safety Audit (LOSA) confirms its position as the international reference model for structured operational observation programs in aviation. LOSA has demonstrated that direct observation of normal operations can generate meaningful safety information while promoting organizational learning, improving risk management processes, and strengthening proactive safety management capabilities.

Equally important, the integration of LOSA with the Threat and Error Management (TEM) framework has provided organizations with a systematic methodology for understanding how operational personnel identify threats, manage errors, recover from undesired states, and maintain safety margins under routine operational conditions (ICAO, 2002; FAA, 2017).

The review of Threat and Error Management further highlights the importance of understanding safety as a dynamic process rather than simply the absence of accidents or incidents. TEM provides a structured framework for analyzing operational performance by examining the interaction between threats, errors, undesired states, and recovery actions. As a result, TEM serves as an essential analytical tool for operational observation programs and provides the conceptual foundation required to transform observational data into meaningful safety information capable of supporting hazard identification, risk management, safety assurance, and organizational learning activities (ICAO, 2018; SKYbrary Aviation Safety, 2023).

Based on these internationally recognized principles and methodologies, this Working Paper proposes the Military Operational Safety Audit (MOSA) as a structured operational observation framework specifically adapted to the operational realities of the Colombian Aerospace Force. MOSA is not intended to replace existing safety management processes, occurrence reporting systems, investigations, or other safety information sources. Instead, it is designed to complement the Manual de Gestión de la Seguridad Operacional (MAGSO) by providing an additional source of operational safety information derived directly from normal military aviation activities. Through this approach, MOSA has the potential to strengthen hazard identification, improve safety risk management, enhance safety assurance activities, and support evidence-based decision-making throughout the organization (Fuerza Aeroespacial Colombiana, 2025).

The proposed framework demonstrates that the successful implementation of MOSA requires the integration of several key elements, including alignment with the MAGSO, a clearly defined operational scope, qualified observers, standardized observer training, structured data collection and analysis processes, and robust information protection mechanisms supported by Just Culture principles. These elements are essential to ensuring the credibility, reliability, and long-term sustainability of the program while maintaining the trust and participation of operational personnel. Furthermore, the adoption of confidentiality, anonymity, and non-punitive observation principles represents a critical requirement for obtaining accurate and meaningful operational information from normal military operations (FAA, 2017; ICAO, 2002; ICAO, 2022).

Ultimately, MOSA represents an opportunity for the Colombian Aerospace Force to strengthen its proactive and predictive safety management capabilities by incorporating operational observation as a formal component of its safety management framework. By

generating direct insight into operational performance, human factors, threat management practices, and organizational influences, MOSA can contribute to a deeper understanding of operational safety and support the continuous improvement objectives established within the MAGSO. As military aviation operations continue to evolve in complexity and operational demands, the implementation of MOSA offers a practical and structured mechanism for enhancing organizational learning, improving operational resilience, and further strengthening the safety performance of the Colombian Aerospace Force (Fuerza Aeroespacial Colombiana, 2025; ICAO, 2018; ICAO, 2022).

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SECCIÓN **4**

MAESO ¿CÓMO VAMOS?

2027-2034

FUERZA AEROSPAZIAL
COLOMBIANA



BRIEFING DE
SEGURIDAD OPERACIONAL

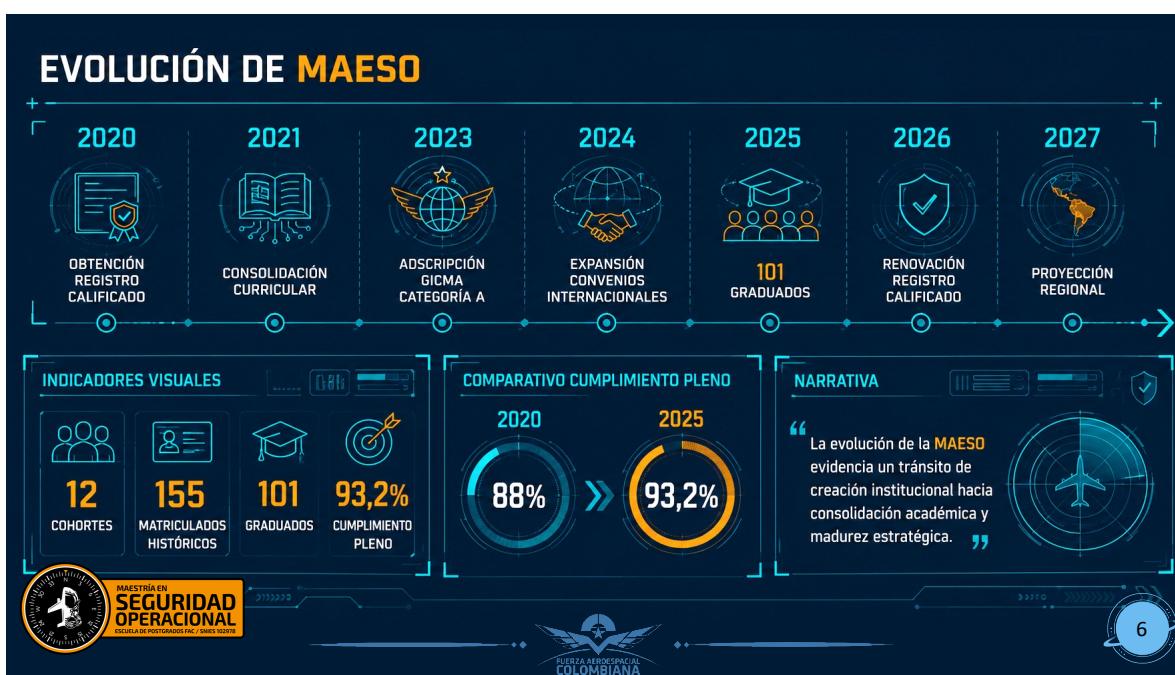


ESCUELA DE
POSTGRADOS
DE LA FAC - EPFAC

4 MAESO ¿CÓMO VAMOS? 2027-2034

Por MY. Francine Pineda Mongui

La Maestría en Seguridad Operacional (MAESO) de la Escuela de Postgrados de la Fuerza Aeroespacial Colombiana (EPFAC) se encuentra adelantando las actividades de preparación para la visita externa de pares académicos, programada dentro del proceso de renovación de su registro calificado. Este ejercicio constituye una oportunidad para evidenciar los avances alcanzados por el programa desde su creación, así como para demostrar el cumplimiento de las condiciones de calidad exigidas para la oferta y desarrollo de programas de educación superior en Colombia.



El registro calificado es el instrumento mediante el cual el Estado colombiano autoriza el funcionamiento de los programas académicos de educación superior y verifica periódicamente el cumplimiento de las condiciones de calidad establecidas por el Ministerio de Educación Nacional. Este proceso se encuentra regulado por la Ley 1188 de 2008 y por el Decreto 1075 de 2015, modificado por el Decreto 1330 de 2019, normativa que orienta la evaluación de los programas en aspectos académicos, curriculares, institucionales y de resultados.

Para la MAESO, la renovación del registro calificado representa un proceso estratégico que permite consolidar su propuesta académica, fortalecer los mecanismos de aseguramiento de la calidad y reafirmar su compromiso con la formación de profesionales

capaces de liderar procesos de gestión de la seguridad operacional y gestión del riesgo en organizaciones aeronáuticas, aeroespaciales y de otros sectores de alta complejidad operacional.

En este contexto, la maestría ha desarrollado un proceso de recopilación, análisis y actualización de evidencias institucionales y académicas que soportan las condiciones de calidad del programa. Como parte de la preparación para la visita de pares académicos, se presentan a continuación las tres primeras condiciones de programa: Condición 1. Denominación, relacionada con la coherencia entre el nombre del programa, su nivel de formación y sus propósitos académicos; Condición 2. Justificación, orientada a demostrar la pertinencia de la maestría frente a las necesidades del entorno; y Condición 3. Aspectos Curriculares, enfocada en la estructura académica, los resultados de aprendizaje y las estrategias pedagógicas que sustentan el proceso formativo de la MAESO.

4.1 Condición n.º1 Denominación



La condición de Denominación busca evidenciar la coherencia entre el nombre del programa, su nivel de formación, el campo de conocimiento que aborda y las competencias que se espera desarrollar en sus estudiantes. En la visita de evaluación externa, la MAESO presenta la evolución conceptual que sustenta su denominación, destacando la transición del término internacional Safety hacia el concepto de Seguridad Operacional, adoptado por la Organización de Aviación Civil Internacional (OACI) y ampliamente utilizado en la aviación civil y militar para referirse a la gestión sistemática de los riesgos asociados a las operaciones

aeronáuticas. Esta evolución permite demostrar que la denominación del programa responde a un campo disciplinar claramente definido y reconocido internacionalmente.

Las diapositivas presentadas a continuación muestran la correspondencia entre la denominación de la maestría y sus características académicas y operativas, en donde se destacan elementos como el nivel de formación de maestría, la modalidad híbrida, la duración de cuatro semestres, la carga académica de 46 créditos y el énfasis en la gestión de la seguridad operacional. Estos aspectos evidencian que la denominación Maestría en Seguridad Operacional refleja adecuadamente los propósitos formativos, el perfil de egreso y el alcance académico del programa, garantizando coherencia entre su identidad institucional y los resultados de aprendizaje que busca desarrollar.



La segunda parte de la presentación profundiza en la coherencia entre la denominación de la MAESO y su desarrollo académico durante los últimos años. Como se observa en las diapositivas, se presenta la evolución histórica del programa desde su creación en 2020, destacando hitos como la obtención del registro calificado, la articulación con la Especialización en Seguridad y Gestión del Riesgo en Operaciones, la expansión de la comunidad académica y el fortalecimiento de los procesos de investigación y proyección institucional. Los indicadores expuestos evidencian el crecimiento sostenido de la maestría, reflejado en el número de estudiantes, trabajos de grado, productos académicos y niveles de permanencia, demostrando la consolidación progresiva del programa dentro de la oferta de posgrados de la EPFAC.



Asimismo, se observa la correspondencia entre la denominación del programa, la estructura curricular y el perfil de egreso. La malla curricular integra componentes de formación profesional, investigación y profundización en seguridad operacional, mientras que el perfil de egreso se orienta al desarrollo de competencias relacionadas con la gestión de riesgos, los sistemas de gestión de la seguridad operacional (SMS), la investigación aplicada, la toma de decisiones basadas en datos y el cumplimiento normativo. Los resultados de autoevaluación presentados evidencian altos niveles de coherencia entre la denominación, los objetivos del programa, el plan de estudios y el perfil del egresado, fortaleciendo la justificación de la denominación Maestría en Seguridad Operacional y su alineación con las necesidades actuales del sector.



4.2 Condición n.º2 Justificación



La condición de Justificación busca demostrar la pertinencia académica, social y sectorial de la Maestría en Seguridad Operacional, evidenciando la necesidad de su existencia y su contribución al desarrollo del sector aeronáutico y de otros entornos de alta complejidad operacional. En la primera parte de la presentación se expone el contexto nacional e internacional de la formación en seguridad operacional, mostrando la limitada oferta de programas especializados en esta área y la creciente demanda de profesionales con competencias avanzadas en gestión de riesgos, investigación de eventos operacionales y sistemas de gestión de la seguridad operacional. Asimismo, se destaca que la MAESO responde a necesidades identificadas tanto en la aviación civil como en la aviación militar, alineándose con las tendencias globales de fortalecimiento de la cultura de seguridad y prevención de accidentes.



De igual forma, la presentación resalta el carácter diferenciador del programa dentro del contexto colombiano, mostrando que la MAESO cuenta con una orientación especializada que la distingue de otras ofertas académicas relacionadas con seguridad, administración o gestión organizacional, al concentrarse específicamente en la seguridad operacional y la gestión del riesgo en operaciones. Esta exclusividad estratégica permite atender requerimientos de instituciones aeronáuticas, operadores aéreos, organismos reguladores y organizaciones que demandan profesionales capaces de gestionar riesgos en entornos altamente regulados y dinámicos, fortaleciendo así la pertinencia y sostenibilidad del programa.



Del mismo modo, la presentación profundiza en los elementos que sustentan la justificación académica de la maestría, exponiendo las tendencias internacionales en formación de posgrado en seguridad operacional, identificando áreas recurrentes como sistemas de gestión de la seguridad operacional, gestión del riesgo, investigación de accidentes, factores humanos y análisis de datos para la toma de decisiones. Este análisis permite evidenciar que la estructura curricular de la MAESO se encuentra alineada con los principales enfoques formativos utilizados a nivel internacional, garantizando la actualización y relevancia de sus contenidos frente a las necesidades actuales del sector.

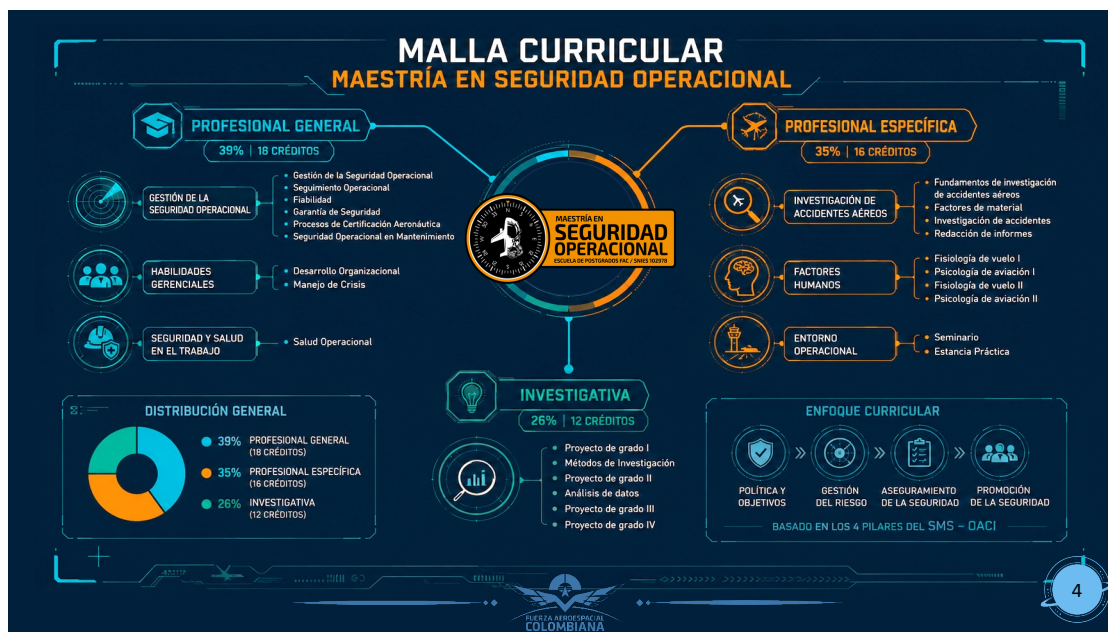


Finalmente, la presentación muestra evidencias del impacto alcanzado por el programa a través de los resultados de sus egresados y de los procesos de autoevaluación institucional. Los indicadores presentados reflejan altos niveles de empleabilidad, desempeño profesional y reconocimiento dentro del sector aeronáutico, mientras que la valoración cualitativa de estudiantes, egresados y actores externos evidencia una percepción favorable sobre la pertinencia y contribución de la maestría. En este sentido, los resultados respaldan la justificación de la MAESO como un programa de profundización orientado a fortalecer capacidades especializadas en seguridad operacional y gestión del riesgo, aportando valor tanto a las organizaciones como al sistema aeronáutico nacional.



4.3 Condición n.º3 Aspectos Curriculares

Por otro lado, la condición de Aspectos Curriculares permite evidenciar la coherencia entre la estructura académica del programa, los perfiles definidos para sus estudiantes y egresados, y los resultados de aprendizaje que orientan el proceso formativo. En la primera parte de la presentación se expone la malla curricular de la MAESO, organizada en componentes de formación profesional, profundización e investigación, los cuales se articulan para desarrollar competencias relacionadas con la gestión de la seguridad operacional, la gestión del riesgo, la investigación aplicada y la toma de decisiones en entornos complejos. Asimismo, se presentan los perfiles de ingreso, egreso y ocupacional, demostrando la correspondencia entre las características de los estudiantes que acceden al programa, las competencias que desarrollan durante su formación y los escenarios profesionales en los cuales podrán desempeñarse.



Esta articulación curricular permite garantizar que los contenidos académicos, las actividades de aprendizaje y los espacios de investigación respondan a los propósitos de formación definidos para la maestría. Del mismo modo, la presentación evidencia que la estructura curricular ha sido diseñada para fortalecer capacidades analíticas, investigativas y de liderazgo, orientadas a la identificación de peligros, la gestión de riesgos y el fortalecimiento de la seguridad operacional en organizaciones aeronáuticas y otros sectores de alta complejidad operacional.



Continuando con la presentación, se profundiza en los mecanismos mediante los cuales se desarrollan y evalúan los resultados de aprendizaje del programa, mostrando una ruta de fortalecimiento progresivo que integra actividades de formación, evaluación y retroalimentación a lo largo de la trayectoria académica del estudiante. Asimismo, se presenta el modelo de evaluación por resultados de aprendizaje implementado por la MAESO, el cual permite verificar el desarrollo de competencias mediante evidencias de desempeño, proyectos aplicados, productos académicos y actividades de investigación alineadas con los objetivos del programa.



Finalmente, se describe el modelo pedagógico que orienta el proceso formativo y los mecanismos de evaluación utilizados para valorar el aprendizaje de los estudiantes, destacando estrategias centradas en el aprendizaje activo, la resolución de problemas, el análisis de casos reales y la aplicación práctica de conocimientos en contextos operacionales. En conjunto, estos elementos evidencian que la MAESO cuenta con una estructura curricular coherente, mecanismos sistemáticos de evaluación y un modelo pedagógico alineado con las exigencias actuales de la educación de posgrado y con las necesidades del sector de la seguridad operacional.



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