DOT/FAA/TC-20/18

Federal Aviation Administration
William J. Hughes Technical Center
Aviation Research Division
Atlantic City International Airport
New Jersey 08405

A Review of Flight Data Monitoring, Risk Management, and Safety Management Tools for Rotorcraft Operations

June 2020

Final Report

U.S. Department of Transportation
Federal Aviation Administration

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/AR-20/18		

4. Title and Subtitle	5. Report Date
A REVIEW OF FLIGHT DATA MONITORING, RISK MANAGEMENT, AND SAFETY MANAGEMENT TOOLS FOR ROTORCRAFT OPERATIONS	June 2020
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
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9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Aerospace Systems Design Laboratory The Daniel Guggenheim School of Aerospace Engineering Georgia Institute of Technology 620 Cherry Street, Atlanta, GA 30332	11. Contract or Grant No. 12-C-GA-GIT-003

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
System Safety Section, ANG-E272 Aviation Research Division, NextGen WJHTC Office Federal Aviation Administration William J. Hughes Technical Center	Final Report
	14. Sponsoring Agency Code FAA, AVP-220

15. Supplementary Notes

The Federal Aviation Administration William J. Hughes Technical Center Aviation Research Division COTR was Charles (Cliff) Johnson.

16. Abstract

Various studies of rotorcraft accidents have shown that the total number of accidents per flight hour is still significantly larger than that for commercial aviation and fixed-wing general aviation. Although rotorcraft accident rates have decreased over the past decade, they have reached a plateau and have even been increasing over the past year. Rotorcraft safety is tightly linked with pilots' actions and the operation of the helicopter, hence the industry has focused on the installation of flight data recorders onboard helicopters and on the use of flight data records for Helicopter Flight Data Monitoring (HFDM). In fact, for several years, the National Transportation Safety Board (NTSB) has recommended the use of FDM systems to improve rotorcraft safety. To facilitate this process, the Federal Aviation Administration is collaborating with world-class researchers, educators, and industry leaders through the Partnership to Enhance General Aviation Safety, Accessibility and Sustainability (PEGASAS) and with the Helicopter Association International (HAI) to examine new ways to analyze and implement HFDM techniques within the overall helicopter community. This report provides a review of software solutions for Flight Data Moniroting (FDM), Risk Management Systems (RMS), and Safety Management Systems (SMS). This review characterizes current state-of-the-art analytical capabilities, key features, data components, information presentation, and several other practical considerations to the safety professional. This review is predicated on the exhaustive enumeration and organization of relevant features of FDM, RMS, and SMS software solutions identified to describe the state-of- the-art as a whole, and a direct comparison of specific solutions. Finally, this review also identifies opportunities to enhance current capabilities that capitalize on the availability and analysis of flight data records and evaluates, prioritizes, and selects basic flight data analysis capabilities on that basis.

17. Key Words	18. Distribution Statement
Rotorcraft Safety Flight Data Monitoring Risk Management Safety Management	This document is available to the U.S. public through the National Technical Information Service (NTIS), Springfield, Virginia 22161. This document is also available from the FAA William J. Hughes Technical Center at actlibrary.tc.faa.gov.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified		

ACKNOWLEDGEMENTS

The authors would like to acknowledge the following persons for their contributions to various parts of the report:

Stuart "Kipp" Lau – then FDM Systems Manager at SKYTRAC and Safety Consultant for HAI; now Pilot and FOQA Committee Chair at UPS

Keith Cianfrani – Aviation Safety Consultants, LLC; Lieutenant Colonel (Ret) U.S. Army; Rotor and Wing Columnist; HAI Safety Committee; USHST SMS Committee; HAI/APS Certified Auditor; IS-BAO Certified Auditor; ISASI Member; Adjunct Instructor Embry Riddle Aeronautical University; Adjunct Instructor Kansas State University; 350 New Britain Road, Doylestown, PA

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LIST OF ACRONYMS

ADS-B	Automatic Dependent Surveillance-Broadcast
AGS	Analysis Ground Station
AHM	Aircraft Health and Maintenance
AirFASE	Air Flight Analysis and Safety Explorer
ALERTS	Aircraft Logging and Event Recording for Training and Safety
AQP	Advanced Qualification Program
ARMS	Airline Risk Management Solutions
ASAP	Aviation Safety Action Program
ASIAS	Aviation Safety Information Analysis and Sharing
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ATC	Air traffic control
CAA	Civil Aviation Authority
CAPA	Corrective Action and Preventive Action
CAS	Collision Avoidance System
CPA	Corrective Preventive Actions
CSV	Comma-separated values
CVR	Cockpit voice recorder
DOD	Department of Defense
EASA	European Aviation Safety Agency
EFIS	Electronic Flight Information System
EMS	(GE Aviation) Event Management System
ERM	Enterprise Risk Management
FAP	Flight Analysis Program
FDA	Flight data analysis
FDAU	Flight data analysis unit
FDE	Flight Data Events
FDM	Flight Data Monitoring
FDP	Flight Data People
FDR	Flight data recorder
FDT	Flight Data Traces
FLIP	Flight Information Program
FMEA	Failure mode and effects analysis
FOD	Foreign object debris
FOIA	Freedom of Information Act
FOM	Flight Operations Management
FOQA	Flight operational quality assurance
FRAT	Flight Risk Assessment Tool
FSO	Flight safety officer
GA	General aviation
GAU	Geospatial awareness unit
GDC	Global Data Center
HDAS	HUMS Data Analyzing System
HFDM	Helicopter Flight Data Monitoring

HUMS	Health and Usage Monitoring System
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
JSON	JavaScript Object Notation
KPI	Key Performance Indices
MDA	Maintenance Data Analyzer
METAR	Meteorological Aerodrome Report
MOQA	Maintenance Operations Quality Assurance
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
ORP	Operational Risk Profile
PEGASAS	Partnership to Enhance General Aviation Safety, Accessibility and Sustainability
PHAT	Proactive Hazard Analysis Tool
QAR	Quick Access Recorder
RADS	Radar Analysis Debriefing System
REST	Representation state transfer
RMS	Risk Management Software
SMS	Safety Management System
SOP	Standard operating procedure
SQL	Structured query language
SRTM	Shuttle Radar Topography Mission
TAR	Terminal Aerodrome Forecast
TFR	Temporary Flight Restriction
TCAS	Traffic Collision Avoidance System
USGS	U.S. Geological Survey
WebDAV	Web-based Distributed Authoring and Versioning

EXECUTIVE SUMMARY

Studies of rotorcraft accidents have shown that the total number of accidents per flight hour is still significantly larger than that for commercial aviation and fixed-wing general aviation. Although rotorcraft accident rates have decreased over the past decade, they have reached a plateau and have actually been slightly increasing over the past year. Since rotorcraft safety is tightly linked with pilots' actions and the operation of the helicopter, the industry has focused on the installation of flight data recorders (FDR) onboard helicopters and on the use of flight data records for Helicopter Flight Data Monitoring (HFDM). In fact, for several years, the National Transportation Safety Board (NTSB) has recommended the use of FDM systems to improve rotorcraft safety.

To facilitate this process, the Federal Aviation Administration (FAA) is collaborating with a national network of world-class researchers, educators, and industry leaders through the Partnership to Enhance General Aviation Safety, Accessibility and Sustainability (PEGASAS) and with the Helicopter Association International (HAI) to examine new ways to analyze and implement HFDM techniques, such as safety tools, policies, and metrics, within the overall helicopter community.

This report provides a review of safety management software solutions based on information extracted from marketing materials such as software providers' websites, online brochures, online fact sheets, and online videos available at the time this report was written. More specifically, this report addresses software solutions for FDM, Risk Management Systems (RMS), and Safety Management Systems (SMS). This review characterizes current state-of-the-art analytical capabilities, key features, data components, information presentation, and several other practical considerations to the safety professional. This review is predicated on the exhaustive enumeration and organization of relevant features of FDM, RMS, and SMS software solutions identified to describe the state-of- the-art as a whole, and a direct comparison of specific solutions. Finally, this review also identifies opportunities to enhance current capabilities that capitalize on the availability and analysis of flight data records and evaluates, prioritizes, and selects basic flight data analysis capabilities on that basis.

1. INTRODUCTION

The Partnership to Enhance General Aviation Safety, Accessibility and Sustainability (PEGASAS) is an FAA Center of Excellence for General Aviation. It was established in December 2012 and constitutes a 10-year partnership with the FAA. The mission of PEGASAS is to enhance general aviation (GA) safety, accessibility, and sustainability by partnering the FAA with a national network of world-class researchers, educators, and industry leaders. PEGASAS supports research efforts by providing world-class researchers well-versed in causal modeling, data mining, analysis, and prototype software-application development.

In particular, PEGASAS is examining new ways to analyze and implement Flight Data Monitoring (FDM) techniques, such as safety tools, policies, and metrics, within the overall helicopter community. This endeavor is known as Helicopter Flight Data Monitoring (HFDM) for ASIAS. HFDM for ASIAS is a system for secure, confidential, and protected safety analysis of flight data records. It is supported by the FAA in its mission to promote and advance flight safety and is being developed and maintained by Helicopter Association International (HAI), an independent third party with strong ties to operators and the industry. Participating operators are key stakeholders, users, and beneficiaries of the system.

1.1 PURPOSE OF THE REPORT

This report provides a review of flight operations safety management software solutions based on information extracted from marketing materials such as software providers' websites, online brochures, online fact sheets, and online videos available at the time this report was written. As a consequence, the information provided in this document reflects what software providers claim their software can do, but may not be exactly aligned with what the software is actually able to do.

This report specifically addresses software solutions for Flight Data Management or Flight Data Monitoring (FDM), Risk Management Systems (RMS), and Safety Management Systems (SMS). The review offers a formal characterization of state-of-the-art analytical capabilities, key features, data components, information presentation, and several other practical considerations to the safety professional. The review is predicated on the exhaustive enumeration and organization of relevant features of FDM, RMS, and SMS software solutions identified to describe the state-of- the-art as a whole, and a direct comparison of specific solutions. The review also identifies opportunities to enhance current capabilities that capitalize on the availability and analysis of flight data records and evaluates, prioritizes, and selects basic flight data analysis capabilities on that basis.

1.2 FLIGHT DATA MONITORING

The European Aviation Safety Agency (EASA) defines an FDM program as "a proactive and non-punitive programme for gathering and analysing data recorded during routine flights to improve aviation safety" [26],[27].

The British Civil Aviation Authority (CAA) also defines FDM as "the systematic, pro-active use of digital flight data from routine operations to improve aviation safety within an intrinsically non-punitive and just Safety Culture" [12].

Following the International Civil Aviation Organization (ICAO) standards and recommendations, both the European Union and the U.K. made FDM a mandatory program for commercial air transport aircraft with a maximum takeoff gross weight in excess of 27,000 kg. They further recommended the application of FDM to air transport operations of aircraft weighing more than 20,000 kg and for helicopters in excess of 7,000 kg or transporting more than nine passengers with a flight data recorder (FDR). According to both the EASA and the CAA, the goal of an FDM program is to [27],[12]:

- "identify areas of operational risk and quantify current safety margins"
- "identify and quantify operational risks by highlighting occurrences of non- standard, unusual or unsafe circumstances"
- "use the FDM information on the frequency of such occurrences, combined with an estimation of the level of severity, to assess the safety risks and to determine which may become unacceptable if the discovered trend continues"
- "put in place appropriate procedures for remedial action once an unacceptable risk, either actually present or predicted by trending, has been identified; and"
- "confirm the effectiveness of any remedial action by continued monitoring"

An FDM program must be designed to not only deal with flight data acquisition and flight data analysis (FDA), but also address FDM analysis, assessment, process control, education and publication, event reporting, data recovery, data retention, data access and security, and data disclosure.

Although FDM was initially required or recommended only for large commercial aircraft and rotorcraft operators, National Aviation Authorities (NAA) in Europe have started to encourage smaller operators to voluntarily report standardized FDM events related to safety concerns shared at the European level.

In the U.S., the FAA refers to FDM as Flight Operational Quality Assurance (FOQA) [39]:

> "Flight Operational Quality Assurance (FOQA) is a voluntary safety program designed to improve aviation safety through the proactive use of flight-recorded data. Operators will use these data to identify and correct deficiencies in all areas of flight operations. Properly used, FOQA data can reduce or eliminate safety risks, as well as minimize deviations from regulations. Through access to de-identified aggregate FOQA data, the Federal Aviation Administration (FAA) can identify and analyze national trends and target resources to reduce operational risks in the National Airspace System (NAS), Air Traffic Control (ATC), flight operations, and airport operations".

Aircraft and rotorcraft operators who choose to implement a voluntary FOQA program can proceed with an FAA-approved or unapproved program. An FAA-approved program allows for mechanisms to share de-identified aggregate data with the FAA while also allowing for protection from punitive actions under Title 14 Code of Federal Regulations Part 13.401 [22]:

> "Except for criminal or deliberate acts, the Administrator will not use an operator's FOQA data or aggregate FOQA data in an enforcement action against that operator or its

employees when such FOQA data or aggregate FOQA data is obtained from a FOQA program that is approved by the Administrator".

An unapproved program lacks these mechanisms and offers no protections under 14 CFR 13.401 to the operator.

Information submitted by an operator under the FOQA initiative with an FAA- approved program is protected from public release under exemption four of the Freedom of Information Act (FOIA) [118]. This protection is meant to "alleviate the aviation community's concerns and allow the data-sharing safety programs to move forward" [48]. As such, there is anecdotal evidence that FOIA has been a significant incentive for operators to seek approval for an FAA-approved program. As a side note, the FAA has been able to offer protection to participants that contribute data under ASIAS (the R-ASIAS counterpart for corporate business and GA aircraft) via existing ASIAS governance structures, regardless of whether or not participants have approved FOQA programs. It is conceivable that the FAA will offer the same protection to rotorcraft operators that voluntarily share data under the HFDM for ASIAS program, regardless of whether their FOQA program is FAA-approved.

In the context of FOQA, flight data are composed of any "pertinent parameters and technical information about a flight" [36]. Such flight data can include parameters enabling reconstruction of the flight path, parameters related to quality of operations, parameters related to the engine, and parameters related to fuel consumption. Some examples for each of the aforementioned categories are provided in Table 1.

Table 1. Flight Data Parameters

Flight path	Quality of operations	Engine operations	Fuel consumption
Latitude	Vertical speed	RPM	Initial and final fuel burn
Longitude	Vertical acceleration	Turbine inlet temperature T4	Duration of flight
Altitude	Lateral acceleration	Inter-turbine temperature (ITT)	
Roll angle	Landing gear compression	Oil temperature	
Pitch angle	Brakes use	Oil pressure	
Yaw angle		Nr	
Heading		Ng	
Airspeed		Tq	
Ground speed		Initial and final oil levels	
Terrain elevation			

In this context, one can perform various types of analyses on flight data:

- Operational safety/risk analysis, which consists in identifying specific parameter exceedances and high-risk events during a flight (e.g., large bank angles during final approach)
- Operational performance analysis, which consists in analyzing fuel consumption, noise, emissions, engine health, and structural integrity to proactively and preventively schedule maintenance activities (for instance, preventive engine maintenance can be scheduled if and when oil consumption reaches a specified level, or preventive landing gear inspection can be planned when a certain number of hard landings have been identified)
- Operational quality analysis, which provides a map of standard operating procedures (SOPs) and helps in identifying conditions that fall outside of this map (e.g., the number of missed approaches)
- Other types of analysis related to aircraft design, air traffic control (ATC) system operation, and weather

Over the years, FDM has been given many different names depending on the type of flight data analysis performed, such as flight data analysis (FDA), Operational Flight Data Monitoring (OFDM), Flight Operations Management (FOM), Daily Flight Operations Monitoring (DFOM), Flight Operational Quality Assurance (FOQA), Flight Operations Data Assurance (FODA), or Maintenance Operations Quality Assurance (MOQA).

Because of the then-controversial meaning of the word “monitoring,” FDM was initially called Flight Operational Quality Assurance (FOQA) [46]. FOQA was initially required or recommended only for commercial air transport operators of heavy aircraft and rotorcraft that performed routine operations. As such, FOQA was mostly a reactive program aimed at determining changes (if any) in safety standards. It was designed to uncover repeated events and to identify deviations from nominal operations by using statistical information from a representative sample of flights. As FOQA became a voluntarily and non-punitive program, the notion of FDM emerged and replaced that of FOQA. Contrary to a FOQA system, an FDM program is proactive in nature. Its goal is to examine safety events from each flight before performing statistical analyses on all of them. Whereas FOQA systems tend to define events as statistical occurrences, FDM systems define events from the organization’s SOPs. For instance, a FOQA system could define an event as “one standard deviation from average bank angle <5° between 200 ft and 500 ft,” whereas the FDM system equivalent would be “bank angle more than 45° or less than -45° between 200 ft and 500 ft.” In the case of rotorcraft operations, both FDM and FOQA may be of interest. The tendency is that FDM comes first and FOQA comes second in a unified process simply called FDM in this document. Finally, despite their small differences, FOQA and FDM are still used completely interchangeably.

Regardless of what one might call it, FDM is meant to enhance the safety of all types of operations. The goal of FDM is to analyze flight data to identify trends, investigate the circumstances behind events, devise early corrective actions to minimize the risk of incidents or accidents, review the effect of corrective actions and make changes if necessary, monitor the effectiveness of the FDM program, and improve operational procedures, safety awareness, and training through reporting. This four-step process (analyze, report, improve, and monitor) is shown in Figure 1. Finally, to benefit from its full potential, FDM should be part of a larger set of tools allowing operators to proactively uncover and address future operational risk. For instance, FDM can interact with other voluntary safety programs, such as the Aviation Safety Action Program (ASAP) and the Advanced Qualification Program (AQP) [38],[37].

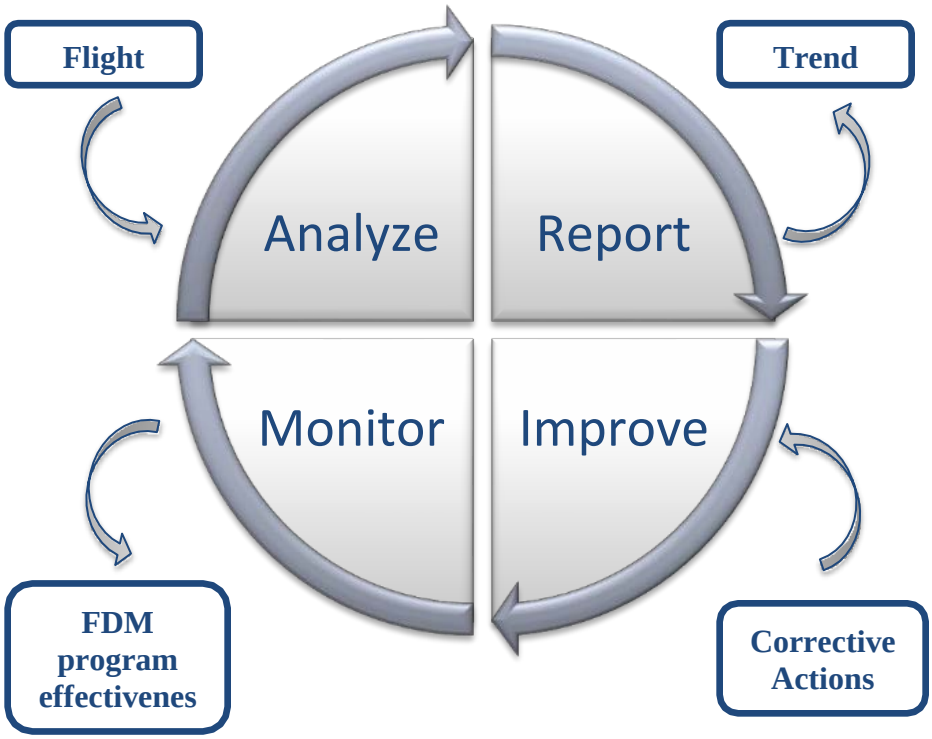

Figure 1. Flight Data Monitoring program

1.3 RISK MANAGEMENT SYSTEMS

FDM programs provide the tools for the proactive identification of hazards and risks. A hazard is defined as a situation or condition that can have negative consequences. As such, they are sometimes linked to an RMS or an Enterprise Risk Management (ERM) System. ERM is defined by ICAO as "the identification, analysis and elimination (and/or mitigation to an acceptable or tolerable level) of those hazards, as well as the subsequent risks, that threaten the viability of an organization" [62]. Risk management is composed of four main elements, as shown in Figure 2:

- Hazard identification – A hazard is a situation or condition that can have negative consequences. Hazards can be reactively or proactively identified from actual safety events (accidents, incidents, and/or near-misses), or from detailed flight data analysis (e.g., exceedances of prescribed operating limitations such as flap limit speeds or engine overheating). A threat is the potential cause to an event that could occur if control over the hazard is lost.

- Risk assessment – A risk is the assessed potential of a hazard to cause harm or damage should it precipitate into a safety event. When a hazard has been identified, its potential impact or consequences can be evaluated. Hazard assessment involves determining the probability that a hazard will lead to a safety event, the severity of the potential consequences, and the duration of exposure to the hazard. Whereas risk assessment can be supported by quantitative methods in some instances, software developers tend to perform aviation risk assessment using critical or logical (qualitative) methods involving facts and relationships. Risk assessment considers both the probability of occurrence of a hazard

and the severity of potential consequences resulting from the realization of the hazard to determine whether the risk associated with this hazard is acceptable, undesirable, or unacceptable. Such a method allows the user/operator to rank risks relative to each other and to allocate resources to the mitigation of corresponding hazards.

- Risk mitigation – If a risk is deemed undesirable or unacceptable, control or corrective measures must be put in place. The goal of risk mitigation is to manage the level of risk to "as low as reasonably practicable" (ALARP). The risk level can be lowered by decreasing either the severity of potential consequences, the probability of occurrence, or the exposure to that risk. Depending on the type of risk, the end product of risk-mitigation strategies will be to either avoid or limit exposure to specific risks, minimize the magnitude of potential consequences, or eliminate the risk altogether by isolating its effects or by building redundancy in the system.

- Risk communication – Once hazards and associated risks are identified and assessed, the existence, nature, severity, level of acceptability, and associated corrective or preventive measures can be communicated both inside the company to relevant employees and outside the company to relevant parties via newsletters, emails, reports, or any other type of communication medium. Sharing lessons learned is an essential component in promoting a positive safety culture within organizations.

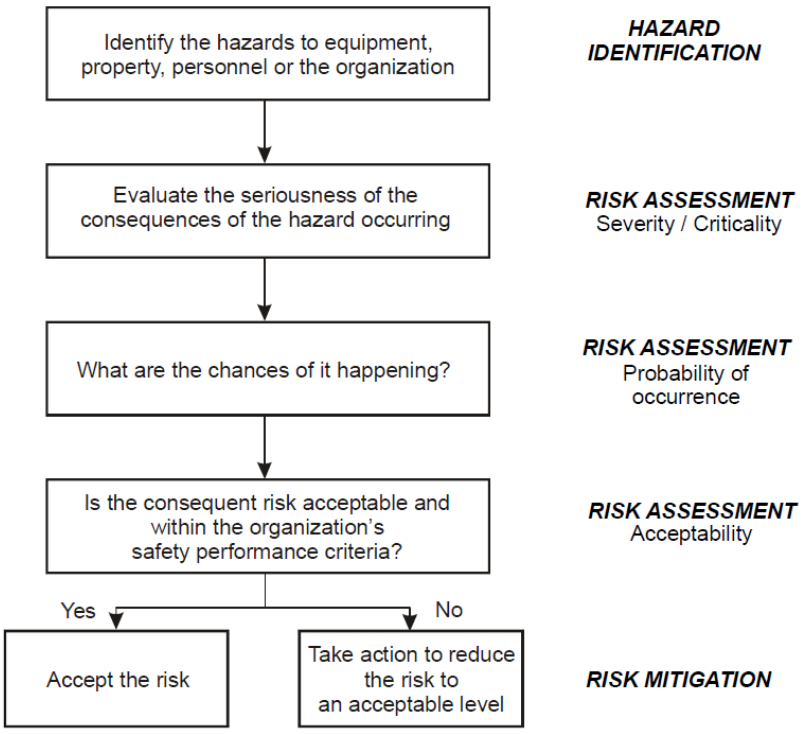

Figure 2. ICAO risk management process [62]

Once the decision to reduce a risk has been made, it is necessary to perform a safety cost-benefit analysis to determine whether the cost of implementing planned corrective measures exceeds the

benefit of implementing such measures. It is also important to take into account the potential for latent hazards or dormant risks that might arise as corrective actions are being implemented, and their probability of occurrence and the severity of their resulting consequences. If this cascading effect is deemed to be acceptable and the cost-benefit analysis favors corrective actions, then the organization needs to make sure that control measures are being handled properly for successful risk mitigation. This task is made possible by a series of processes and systematic actions. In particular, safety risk management is only one of the four pillars of an efficient SMS.

1.4 SAFETY MANAGEMENT SYSTEM

According to ICAO, safety assurance is one of the four pillars of an SMS. An SMS is a set of "systematic, explicit and comprehensive processes for the management of safety risks, that integrates operations and technical systems with financial and human resource management, for all activities related to an air operator or an approved maintenance organization" [115].

The major characteristic of an SMS is its proactive nature (i.e., its ability to anticipate and potentially prevent incidents or accidents). At a minimum, an SMS must identify safety hazards, ensure that corrective actions are implemented to maintain acceptable safety levels, continuously monitor and assess safety, and continuously improve the overall level of safety within the organization. An SMS must provide a systematic way to identify hazards and control risks, and provide assurance that those risk controls are effective [40]. ICAO conceptualizes these minimum safety standards into four components and twelve elements [63],[64],[109]:

- Safety policy, which includes:
  - Management commitment and responsibility (definition of a safety policy statement)
  - Safety accountabilities (definition of safety responsibilities for both managers and employees)
  - Appointment of key safety personnel (for daily oversight functions of the SMS)
  - Coordination of emergency response planning (including a business continuity contingency plan)
  - SMS documentation (about all SMS activities for all employees to access)
- Safety risk management, which includes:
  - Hazard identification (using reactive, proactive, and predictive safety management methods)
  - Safety risk assessment and mitigation (including analysis, consequences assessment and communication, and mitigative actions development)
- Safety assurance, which includes:

- Safety performance monitoring and measurement (including monitoring of both internal and external sources of safety information, and participation in safety groups or safety data sharing activities)
- The management of change (to manage organizational responses to regulatory changes, changes in operational procedures, and new activities; to identify new risks and monitor performance in new areas of operations)
- Continuous improvement of the SMS (using internal evaluations or external audits)

- Safety promotion, which includes:

  - Training and education (to ensure compliance with operating and safety procedures, to facilitate recognition and reporting of hazards, and to ensure employees knowledge and skills to safely perform job-related activities)
  - Safety communication (including sharing of lessons learned and feedback to operational personnel)

First, safety policy establishes the management framework, the required processes and procedures for the SMS. Once established, the primary functional processes of the SMS are the safety-risk management and the safety assurance components. Finally, safety promotion permeates all the SMS components in the organization [40].

Safety policy clearly states safety objectives and management commitment to safety performance, defines methods and processes required to meet safety goals, documents policy and processes, and facilitates communication and cooperation across all organizational levels.

Safety-risk management establishes a process to describe the system, identify hazards, and assess, analyze, and control risks. Risk analysis and assessment consist of defining the severity and probability of occurrence of identified risks. A causal analysis can also be performed before developing and implementing methods to control risks to acceptable levels.

Safety assurance supports the identification of new hazards and the effective implementation of risk control strategies. It includes ensuring compliance with SMS requirements and FAA orders, standards, policies, and directives through audits, evaluations, reporting, data analysis, and system assessment. It also enables the development of methods for improving safety and minimizing risks, for instance by defining, implementing, and tracking corrective actions.

Safety promotion consists in maintaining a positive safety culture, ensuring communication and awareness of safety actions, disseminating safety reports, sharing relevant data with interested parties, ensuring continuous training of concerned parties, and promoting general safety in the organization.

1.5 RELATIONSHIP BETWEEN FDM, RMS, AND SMS

In the aforementioned definitions, safety refers to enterprise safety and, therefore, encompasses the operational, technical, environmental, financial, and social safety components. In this context,

FDM addresses the operational, and to some extent, technical aspects of safety. It directly enables operational safety assurance, but also provides a medium for operational safety risk management, operational safety promotion, and, to a lesser extent, operational safety policy. Indeed, FDM contributes to increasing operational (flight) safety by providing data necessary to analyze and potentially prevent incidents and accidents, to identify potential risks and hazards, to improve operational procedures (related for example to fuel consumption, maintenance and repairs, ground and airport operations, and noise), to maintain or improve operational compliance, and to promote pilot training.

However, FDM does not directly and explicitly address the environmental, financial, and social aspects of safety. Rather, it provides a framework and the data necessary to perform such safety analyses. Finally, in addition to enabling operational safety management, FDM provides insight into operational quality and operational performance that are not explicit elements of an efficient SMS. Similarly, whereas safety risk management is intended to deal with risk affecting enterprise safety, ERM includes methods and tools that allow organizations to manage all types of risks, such as safety-related, operational, environmental, financial, social, reputational, and legal. Again, whereas FDM directly addresses operational risk, it does not explicitly deal with other types of risks. In this more general picture, enterprise management can be divided into three interconnected pieces, namely enterprise operations management (facilitated by FDM), ERM, and enterprise safety management. There may exist other elements to enterprise management, but the aforementioned three components together provide an integrated enterprise management framework aimed at both creating and maintaining business value.

The above relationships between FDM, RMS, and SMS elements are shown in Figure 3.

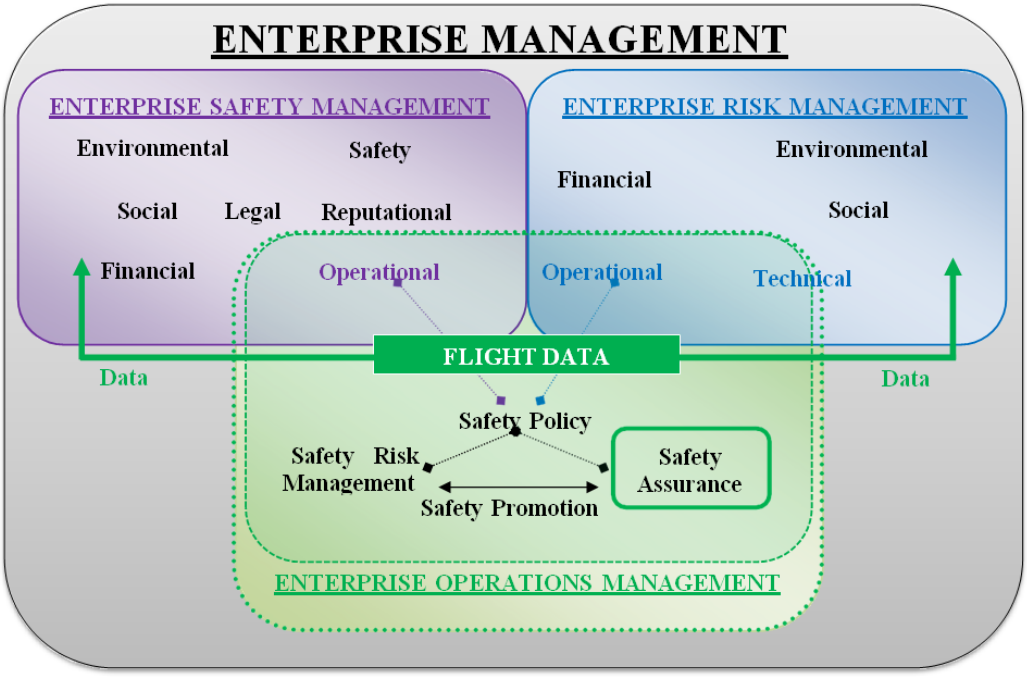

Figure 3. FDM, SMS, RMS relationship

The accepted paradigm in FDM for rotorcraft operations has long been to inform and facilitate corrective actions from flight data records to enhance future operational safety. A paradigm shift from a retrospective to a preventive use of flight data records, and therfore from a reactive to a proactive helicopter FDM (HFDM) program, has been occurring in recent years to respond to the changing global environment. Whereas the main purpose of HFDM remains to promote safety for all types of operations by evaluating operational trends, it has evolved to include a set of tools addressing issues such as identification of triggers to incidents and risk precursors, preventive maintenance, fuel consumption monitoring, engine health monitoring, fatigue monitoring, operational environment analysis, and so on. Over the years, FDM has also become an essential part of efficient SMS and RMS because of technology advancements in flight data acquisition units (FDAUs) and wireless communications. For instance, FDAUs are of better quality, are able to capture larger numbers of flight parameters, and are becoming less intrusive and more affordable. As for wireless technologies, such as Wi-Fi and high-speed Internet and satellites, they are speeding up the distribution of flight data records and the dissemination of the corresponding analysis results to various interested parties.

1.6 ORGANIZATION OF THE REPORT

The remainder of this report is organized as follows. Section 2. offers a summary of the basic data analysis capabilities provided by a variety of operational safety management software found in the domain of FDM/FOQA in the form of an organized table. Each tool identified is then described in detail in an appendix through a suite of snapshots and descriptions. In Section 3. and Section 4. of the report, a similar approach is followed for software solutions identified in the domains of ERM and enterprise safety management, independently of or in conjunction with FDM. A table summarizes the main capabilities offered by these SMS and RMS, and corresponding detailed descriptions are provided in appendices. Finally, the last section of the report focuses on the evaluation, prioritization, and selection of basic data analysis capabilities to implement as part of an FDM program and concludes with the identification of new opportunities to use flight data records.

2. FLIGHT DATA MONITORING SOFTWARE

Table 3 provides an organized summary of the major characteristics of operational safety software identified in the domain of FDM/FOQA. The information provided in Table 3 has been extracted from marketing materials, such as software providers' websites, online brochures, online fact sheets, and online videos available at the time this report was written. As a consequence, there is no guarantee that the information summarized in Table 3 is accurate or represents current functionality. It may not reflect what a software is actually able to do but rather what the software provider claims the software could do when the information was retrieved. Finally, note that the information in Table 3 may have changed since this report has been written and published.

The major goal of an FDM software solution is to turn data into useful information that can be translated into knowledge, as summarized in Figure 4.

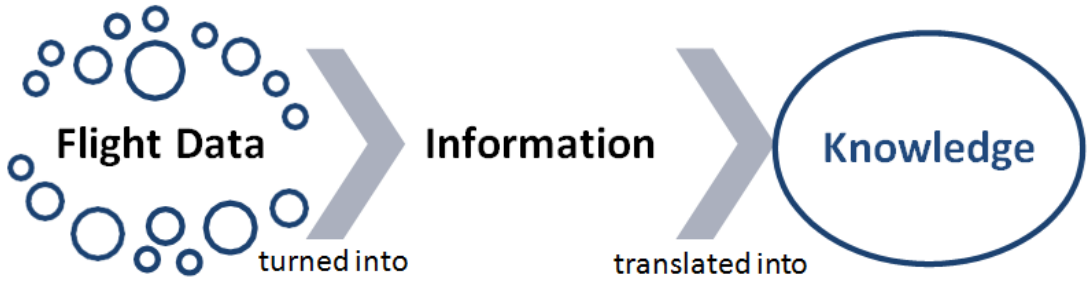

Figure 4. FDM software structure

Several criteria have been down-selected to facilitate the comparison of the FDM software solutions identified. These criteria concern the type of service provided (full service or hosted), data access and storage, support, ease of use, automation and functionality, analysis and visualization capabilities, customizability, drill-down capability (hierarchical analysis of events), corrective actions implementation and tracking, performance monitoring and management, safety management, operational quality monitoring, risk monitoring and analysis, analysis results export flexibility, use of data for training purposes, and information-sharing capability.

In general, the FDM software solutions identified perform four major tasks on the flight data: flight data analysis, risk analysis and monitoring, operational quality assurance, and flight replay. These software solutions are based on various information technology requirements concerning the access and storage of flight data using secure web transfer protocols (WebDAV, industry standard HTTPs, XML-RPC, SHA1, JSON, representation state transfer (REST), BZIP2 compression algorithm, Geo IP tracking, and structured query language (SQL) server), scripting platforms (Ubuntu [116], Windows® Vista™, Oracle® Java [68], and .NET [80]), and scripting languages for the web server and the transfer client (Python™ [89], Django [24], PostgreSQL [84], Apache [6], wxPython [123], FilterPype [41]). Finally, the FDM software solutions identified are generally compliant with one or more of the regulations overseeing the implementation of FDM programs in aviation across the world (14 CFR Part 13, ICAO, EU or JAA (JAR-OPS 1.037), CAP 739, and IOSA).

2.1 FLIGHT DATA ANALYSIS

FDM programs typically involve several airborne and ground-based systems that: 1) capture and record flight data, 2) transfer the recorded flight data to a ground-based processing station, 3) transform this raw data into engineering units for validation, categorization, and classification, and 4) analyze or replay the transformed data to identify exceedances and generate reports to assist in monitoring the effectiveness of the FDM program, and in improving SOPs, safety awareness, and training. FDM programs are therefore sometimes referred to as the four R's process shown in Figure 5.

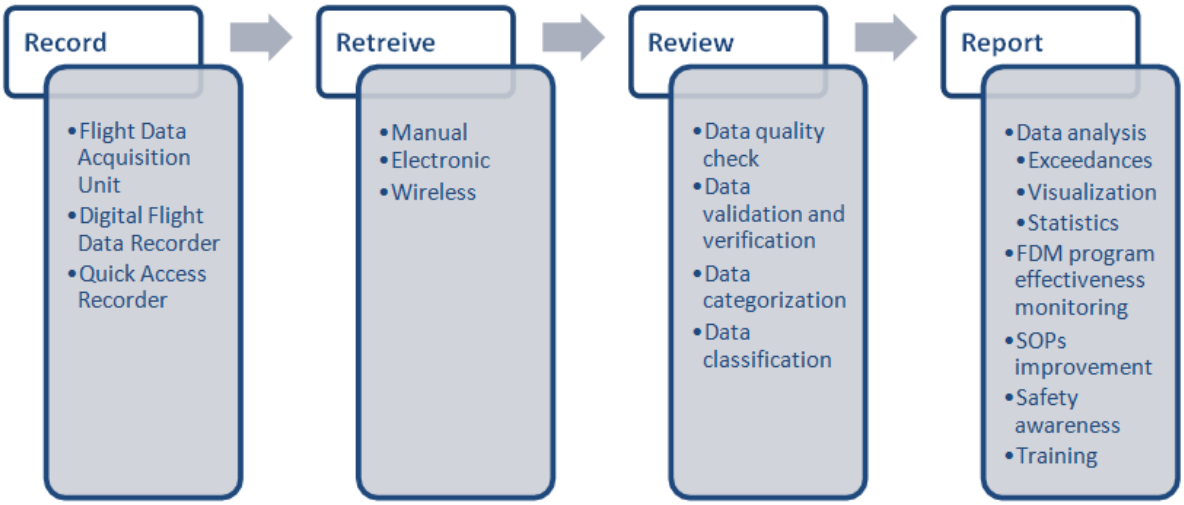

Figure 5. Four R's process

Flight data obtained from a variety of recording devices onboard the rotorcraft (such as those identified in Table 1) can be manipulated to derive information about the safety/risk, quality, and performance of operations.

According to the EASA, an FDM analysis should comprise at least exceedance detection, all flights measurement, and statistics [27].

In general, most of the large software vendors can process data from multiple sources (especially from various FDRs). This is the case for CAE Flightscape, Flight Data Services, Safran, Airbus/Navblue, and Aerobytes. However, some of the smaller companies can process data only in a comma-separated values (CSV) format (such as CAPACG FlyteAnalytics) or from their own FDRs (such as Appareo, which can process only Appareo data).

Some of the most common flight data analysis features among the surveyed FDM software solutions include:

- Events definition, verification (to exclude false alarm), and categorization
- Single-event or multiple-event detection and investigation for a single flight or multiple flights
- Single-flight parameters monitoring
- Safety summary reporting
- Statistical analysis (analysis performed on a representative sample of flights to isolate repeated events or to identify potential variations from a baseline of SOPs or of nominal flight parameters)
- Trend analysis (collection of flight information to attempt to spot a pattern or a trend in this information)
- Retrospective analysis (analysis of past events to examine risk exposure)

- Proactive/predictive analysis (analysis of both current and past events to make predictions about potential future events and to facilitate the development of corrective/preventive/mitigative measures)
- Comparative analysis (concurrent analysis of flight data across a community to derive conclusions about the global safety environment, or comparison of one's operational safety/risk, performance or quality levels with other members of the same community)

Fewer than half of the software solutions surveyed also have the ability to implement and track corrective actions to improve safety, quality, and performance of operations, whereas a very small number of them are able to perform some kind of predictive analysis through data mining or to analyze the root causes of an event (i.e., parameters and exceedances leading to the development of an event), also called drill-down capability.

Various other sources of data can be used to make the analysis of flight data more complete. For instance, the FAA, the Department of Defense Flight Information Program (FLIP), the Georgia Tech Falcon View, Aircraft Communications Addressing and Reporting System, the Honeywell Global Data Center (GDC), and Jeppessen provide airport data, ATC data, surveillance radar data, weather data, pilot reports, navigation data, and terminal or sectional area data. National Oceanic and Atmospheric Administration (NOAA) satellites provide satellite weather data. NASA/Jet Propulsion Laboratory missions, such as the Shuttle Radar Topography Mission (SRTM) and the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model, and the U.S. Geological Survey (USGS) National Elevation Dataset (NED) provide terrain elevation data. Rotorcraft operators can provide their own operational data, such as flight scheduling and mission planning. In addition to flight data from FDRs and cockpit voice/video recorders, approximately half of the FDM software solutions surveyed use airport-related data, such as runway information, instrument flight rules (IFR) approach procedures, and ATC procedures and communications. A smaller number of software solutions also use radar or satellite data providing weather information, such as wind direction and speed, visibility, cloud coverage, and precipitation type and intensity, when appropriate.

Finally, various data reporting and exporting schemes have been identified, such as Microsoft® Excel®, Microsoft® Word®, Adobe® PDF, HTML, 3D flight KML, and CSV.

2.2 RISK ANALYSIS AND MONITORING

Approximately three-fourths of the FDM software solutions identified perform some kind of risk/safety analysis and monitoring through the use of a risk matrix. A risk matrix enables the visualization of event clusters. In a risk matrix, each event of interest can be characterized by a pair of values for severity and probability of occurrence, which are the two axes of a corporate risk matrix.

Both the severity and the probability of occurrence for a given event are used to determine its risk index. The degree to which an event is manageable is then determined with the use of a risk-tolerability matrix, which maps risk index ranges from previous assessments with agreed-upon levels of acceptance.

Using such a simplified risk-assessment method, it may be possible to identify the areas of highest risk (e.g., airports, taxiways, and operating procedures). Nevertheless, this identification requires aggregating large sets of high-quality and low-frequency data that would most probably have to be shared voluntarily among operators.

It is worth noting that, whereas the majority of surveyed FDM software vendors claim they are capable of providing some sort of risk analysis using flight data, most of them are rather vague about what they can actually do and how they actually do it. However, some of the identified FDM software vendors clearly state that they collaborate with more advanced risk management tools to perform this risk-analysis task. Some of these other tools dealing specifically with risk management (assessment and monitoring) that could be applicable to FDM have been identified in the literature and are described further in Section 3. .

2.3 OPERATIONAL PERFORMANCE, AND HEALTH AND USAGE MONITORING

Among the FDM software solutions identified, operational performance and Health and Usage Monitoring (HUM) mainly entail the monitoring of several aircraft and engine performance parameters to gain insight into the safety of the operations and assess the efficiency of potential corrective actions when applicable. Such parameters include fuel consumption, engine health, brakes and tires health, SOPs, and structural integrity.

2.4 FLIGHT REPLAY

All of the FDM software solutions surveyed provide the option to replay flight data and sometimes integrate audio and video data into the replay. The flight is typically replayed with flight visualization software that can combine both 2D and 3D animations. Several products that provide the framework for 2D and 3D flight replay animations are available, for example:

- Airbus-NAVBLUE AirFASE® Flight Animation [5]
- CAE Flight Animation Software Insight Animation [16]
- SimAuthor FlightViz® [108]
- RTI 720° Smart Animation [99]
- Guardian® Mobility Mapping [55]
- Flight Explorer (Professional® or Select® edition) [45]
- Flight Simulator [75]
- X Plane [127]
- Exosphere 3D [35]
- WingX™ [122]
- Google Earth™ [53]
- Google Maps™ [54]

In general, most FDM software solutions can output a CSV file that can be converted into an X-Plane FDR file for visualization. The majority of FDM software can also create a Keyhole Markup Language (KML) file that can be read by Google Earth and Google Maps. In general, software vendors seem to downplay these facts to the benefit of their own animation software. Table 2 summarizes the flight replay software programs that are part of a suite of FDM tools.

Table 2. Flight Replay Software

FDM Software Solution	Visualization Software for Flight Replay
Airbus-NAVBLUE AirFASE®	Airbus-NAVBLUE AirFASE® Flight Animation
CAE Insight tool suite	CAE Insight Animation
SimAuthor tool suite	SimAuthor FlightViz
Flight Data People FDM360	RTI 720° Smart Animation
Guardian FDM solution	Guardian Mobility Mapping

AirFASE = Air Flight Analysis and Safety Explorer

As for Flight Explorer, Flight Simulator/X Plane, Exosphere 3D, WingX, and Google Maps/Earth, they are standalone 2D/3D visualization software that can be used in combination with a standalone FDM program.

Finally, with the exception of Google Maps and Google Earth Free Edition, all these software packages come at a cost, whether it be with an FDM package or as a standalone. Some other potential flight replay software includes FlyHigh (free, uses Google Maps and Google Earth), CompeGPS (Air version), IGC Flight Replay (free, uses Google Earth), NavITer SeeYou (free), Cartofly from Logfly (2D), SkyKick from Skywind (more adapted to gliders, hanggliders, and paragliders), and StrePla.

2.5 GENERAL OBSERVATIONS AND MISSING CAPABILITIES

This survey of FDM software solutions is extensive, but it is by no means exhaustive. It includes some of the major elements found in the publicly available literature. Based on our survey, an efficient FDM system should have at least the following basic capabilities:

- Flight data analysis, in particular events and parameters monitoring through statistical analysis, trend analysis, and retrospective analysis
- Flight replay (2D or 3D), including airport procedures data, ATC data, weather data, and terrain elevation data

Some additional interesting capabilities may include basic operational risk management, operational performance and health and usage monitoring, and predictive analysis.

Note that regulatory compliance claimed by most FDM software providers is mainly for marketing. Regulatory compliance is typically accomplished through FDM program management. Regulators typically look at the FDM program and not at the software designed to implement the program.

Finally, in the enterprise SMS scheme, FDM addresses most parts of the last three pillars in the operational domain, namely operational safety assurance, operational safety risk management, and operational safety promotion. Some information is nevertheless missing when it comes to the first overarching safety pillar – safety policy. Therefore, various other SMS software solutions dealing with enterprise safety as a whole have been researched. In Section 4. , we identify a set of capabilities that are necessary to obtain a globally efficient enterprise SMS.

Table 3. Flight Data Monitoring tool capabilities summary

SOFTWARE PROVIDER	Aero-bytes	Appareo ALERTS	Helinalysis®	GE Aviation EMS	CAE Flight-scape INSIGHT	Flight Data Services Flight Data Connect	Airbus/ Navblue AirFASE	Safran CASSIOPÉE	Swiss 49	CAPACG Flyte-Analytics	Wi-flight	BA-RTI forensics	Sim Author FLIGHT-ANALYST + FLIGHT VIZ	Guardian
Event-specific information	x		x	x	x	x	x	x	x	x	x	x	x	
Event detection	x	x	x	x	x		x	x	x	x		x	x	x
Event clustering						x				x	x	x	x	
Event durations display					x									
Event categorization	x		x	x	x		x	x		x	x	x	x	
Abnormal events detection	x	x	x		x		x	x	x	x	x	x	x	x
False-alarm detection /event verification	x	x	x	x	x		x	x				x	x	
New events definition	x		x		x			x					x	
Corrective actions implementation	x				x		x	x		x				
Retrospective analysis	x	x	x	x	x	x	x	x	x	x	x	x		x
Statistical reports/tools	x	x	x	x	x	x	x	x	x	x	x		x	x
Data mining				x					x					
Drill-down/hierarchical data display	x					x						x	x	
Data relationships								x		x	x	x		
Individual customization		x	x		x	x		x			x		x	

Table 3. Flight Data Monitoring tool capabilities summary (continued)

SOFTWARE PROVIDER	Aero-bytes	Appareo ALERTS	Helinalysis	GE Aviation EMS	CAE Flight-scape INSIGHT	Flight Data Services Flight Data Connect	Airbus/ Navblue AirFASE	Safran CASSIOPÉE	Swiss 49	CAPAC G Flyte-Analytics	Wi-flight	BA-RTI forensics	Sim Author FLIGHT-ANALYST + FLIGHT VIZ	Guardian
Departure and approach			x					x	x			x	x	
Takeoff and landing			x				x	x	x			x	x	x
Maneuvers	x	x	x					x				x	x	
Headwind and crosswind	x	x	x				x		x		x		x	
Groundspeed	x	x	x				x	x	x		x	x		x
Altitude	x	x	x				x	x	x		x	x		x
Vertical speed	x		x				x	x	x		x	x		
Loads			x								x		x	x
Low-level flight			x	x					x		x	x		x
Off-airport landing								x			x			x
Restricted airspace violations											x			x
Exceedances		x	x	x			x	x	x	x	x	x	x	x
Parameters analysis	x		x	x	x	x		x	x	x	x	x	x	x
Flap	x								x					x
Trend		x	x	x	x	x	x	x		x	x	x		x
General	x	x		x		x	x	x	x	x		x		
Risk matrix	x								x					
Highest risk identification	x			x		x								
Risk-based event analysis	x						x							
Heat map														

Table 3. Flight Data Monitoring tool capabilities summary (continued)

SOFTWARE PROVIDER	Aero-bytes	Appareo ALERTS	Helinalysis	GE Aviation EMS	CAE Flight-scape INSIGHT	Flight Data Services Flight Data Connect	Airbus/ Navblue AirFASE	Safran CASSIOPÉE	Swiss 49	CAPAC G Flyte-Analytics	Wi-flight	BA-RTI forensics	Sim Author FLIGHT-ANALYST + FLIGHT VIZ	Guardian
Operational Quality Assurance														
Fuel consumption monitoring	x			x		x	x	x	x	x			x	x
Engine health monitoring	x		x	x			x	x	x	x	x		x	x
Performance monitoring	x	x		x	x		x	x	x	x			x	x
Brake and tire monitoring			x	x			x	x			x	x	x	
Maintenance monitoring	x		x	x	x	x	x	x	x	x			x	x
SOPs monitoring			x			x	x	x	x	x			x	
Safety management	x	x		x	x	x	x	x	x	x		x		x
Value analysis	x					x		x						
Benchmarking						x			x					
General	x	x		x	x	x	x	x	x		x	x	x	x
Flight Explorer					x									
CEFA Flight Animation Software								x						
RTI 720° Smart Animation												x		
Google Earth					x	x	x	x	x		x	x		x
Google Maps					x	x	x	x	x		x	x		x
CAE Flightscape RADS					x									

Table 3. Flight Data Monitoring tool capabilities summary (continued)

SOFTWARE PROVIDER	Aero-bytes	Appareo ALERTS	Helinalysis	GE Aviation EMS	CAE Flight-scape INSIGHT	Flight Data Services Flight Data Connect	Airbus/ Navblue AirFASE	Safran CASSIOPÉE	Swiss 49	CAPAC G Flyte-Analytics	Wi-flight	BA-RTI forensics	Sim Author FLIGHT-ANALYST + FLIGHT VIZ	Guardian
Airbus-NAVBLUE AirFASE® Flight Animation							x							
WingX										x				
X Plane (from CSV file)	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Guardian Mapping														X
General	x				x	x	x	x	x		x		x	x
Flight scheduling /mission planning	x				x				x		x		x	
Air traffic control procedures		x		x	x	x		x	x		x	x	x	
Runways	x	x		x	x		x	x	x		x	x	x	
Jeppessen airport database	x						x	x				x	x	
Jeppessen IFR plate							x	x				x	x	
DoD FLIP							x							
Falcon View							x							
General					x			x	x		x		x	x
METAR				x		x		x			x			
Wind	x					x					x			
NOAA satellite	x													
General	x	x			x		x	x	x		x	x	x	x
NED											x			

Table 3. Flight Data Monitoring tool capabilities summary (continued)

SOFTWARE PROVIDER	Aero-bytes	Appareo ALERTS	Helinalysis	GE Aviation EMS	CAE Flight-scape INSIGHT	Flight Data Services Flight Data Connect	Airbus/ Navblue AirFASE	Safran CASSIOPÉE	Swiss 49	CAPAC G Flyte-Analytics	Wi-flight	BA-RTI forensics	Sim Author FLIGHT-ANALYST + FLIGHT VIZ	Guardian
SRTM		x									x			
ASTER											x			
Appareo Database		x												
Surveillance radar					x				x					x
Pilot reports						x		x					x	
Images/photos/ data/plate overlays	x				x		x	x	x					x
Satellite		x			x	x	x	x						x
FAA		x			x	x		x	x			x	x	x
Operational		x		x	x		x	x	x		x	x	x	x
Flight	x	x		x	x	x	x	x	x		x	x	x	x
Aircraft	x	x		x	x	x	x	x	x	x	x	x	x	x
Area charts/Nav charts							x	x	x			x	x	
Engine	x			x			x	x	x	x	x	x	x	x
Video	x	x		x	x		x	x					x	
Audio		x			x		x	x			x	x		
Microsoft Excel			x											
Microsoft Word							x						x	
Adobe PDF								x					x	
HTML								x				x		
XLS								x						

Table 3. Flight Data Monitoring tool capabilities summary (continued)

SOFTWARE PROVIDER	Aero-bytes	Appareo ALERTS	Helinalysis	GE Aviation EMS	CAE Flight-scape INSIGHT	Flight Data Services Flight Data Connect	Airbus/ Navblue AirFASE	Safran CASSIOPÉE	Swiss 49	CAPAC G Flyte-Analytics	Wi-flight	BA-RTI forensics	Sim Author FLIGHT-ANALYST + FLIGHT VIZ	Guardian
3D flight KML	x	x	x	x	x	x	x	x	x	x	x	x	x	X
CSV file	x	x	x	x	x	x	x	x	x	x	x	x	x	X
Graphs, charts	x	x	x		x	x	x	x	x		x	x	x	
Curve fitting	x	x			x	x	x	x		x				
Moving averages														
Interactive dashboard					x	x		x			x	x		
Drag and drop														
Trends and patterns		x	x	x	x	x	x	x		x	x	x	x	
Cockpit displays	x	x			x	x	x	x	x			x	x	
Airport view						x		x	x		x	x	x	
Switch between views	x							x				x	x	
Flight paths	x	x			x	x	x	x	x		x	x	x	
Trajectory correction				x				x	x					
Key points marking	x					x		x	x				x	
Zoom	x	x					x					x		
General	x		x		x			x	x			x	x	x
Avionica mini-QAR				x		x								
L3 mini-QAR				x		x								
Flight Data Vision SSQAR						x								

Table 3. Flight Data Monitoring tool capabilities summary (continued)

SOFTWARE PROVIDER	Aero-bytes	Appareo ALERTS	Helinalysis	GE Aviation EMS	CAE Flight-scape INSIGHT	Flight Data Services Flight Data Connect	Airbus/ Navblue AirFASE	Safran CASSIOPÉE	Swiss 49	CAPAC G Flyte-Analytics	Wi-flight	BA-RTI forensics	Sim Author FLIGHT-ANALYST + FLIGHT VIZ	Guardian
Penny+Giles OQAR				x		x								
Penny+Giles PQAR				x		x								
Teledyne QAR						x	x							
Thales EQAR						x			x					
General	x		x		x	x	x	x			x	x	x	x
ARINC 429	x				x	x	x	x			x			
Avionica RSU-II	x			x	x	x	x	x						
AMS Afirs	x				x	x	x	x						
L3 F1000	x			x	x	x	x	x						
L3 FA2100	x			x	x	x	x	x						
L3 ROSE	x			x	x	x	x	x						
Safran DFDAU	x			x	x	x	x	x						
Safran MFDAU	x				x	x	x	x						
Appareo GAU 2000	x	x			x	x	x	x						
Appareo Vision 1000	x	x			x	x	x	x						
Honeywell SSFDR	x			x	x	x	x	x						
General					x				x					
FDS HHMPI						x								
Honeywell Handheld Dowload Unit				x		x								
Honeywell FDAMS				x		x								
Safran FDIMU				x		x		x						
Teledyne FDIMU							x							

Table 3. Flight Data Monitoring tool capabilities summary (continued)

SOFTWARE PROVIDER	Aero-bytes	Appareo ALERTS	Helinalysis	GE Aviation EMS	CAE Flight-scape INSIGHT	Flight Data Services Flight Data Connect	Airbus/ Navblue AirFASE	Safran CASSIOPÉE	Swiss 49	CAPAC G Flyte-Analytics	Wi-flight	BA-RTI forensics	Sim Author FLIGHT-ANALYST + FLIGHT VIZ	Guardian
Teledyne FDFDAU							x							
Teledyne WGL						x	x							
Appareo Transfer Utility		x												
General								x						x
Safran ART and ART2								x						
CVR												x		
Safran AGS								x						
Guardian 7-FDM														X
WebDAV						x								
industry standard HTTPs						x								
XML-RPC						x								
SHA1						x								
JSON						x								
REST						x								
BZIP2 comp. algo.						x								
Geo IP tracking						x								
SQL server (financial institutions)	x				x		x							

Table 3. Flight Data Monitoring tool capabilities summary (continued)

SOFTWARE PROVIDER	Aero-bytes	Appareo ALERTS	Helinalysis	GE Aviation EMS	CAE Flight-scape INSIGHT	Flight Data Services Flight Data Connect	Airbus/ Navblue AirFASE	Safran CASSIOPÉE	Swiss 49	CAPAC G Flyte-Analytics	Wi-flight	BA-RTI forensics	Sim Author FLIGHT-ANALYST + FLIGHT VIZ	Guardian
Ubuntu														
Windows		x			x			x						
Vista														
Java														
.NET														
Python						x								
Django						x								
PostgreSQL						x								
Apache						x								
wxPython						x								
FilterPype						x								
FAA 14 CFR Part 13				x	x		x							
ICAO				x	x		x	x						
EU or JAA (JAR-OPS 1.037)				x	x		x	x	x					
CAP 739							x							
IOSA								x						
Full service			x		x	x	x	x	x			x	x	
Hosted		x	x	x	x	x		x	x		x	x	x	
Secure data access and storage	x			x	x	x	x	x	x		x	x	x	
Support	x						x	x	x		x	x		

Table 3. Flight Data Monitoring tool capabilities summary (continued)

SOFTWARE PROVIDER	Aero-bytes	Appareo ALERTS	Helinalysis	GE Aviation EMS	CAE Flight-scape INSIGHT	Flight Data Services Flight Data Connect	Airbus/ Navblue AirFASE	Safran CASSIOPÉE	Swiss 49	CAPAC G Flyte-Analytics	Wi-flight	BA-RTI forensics	Sim Author FLIGHT-ANALYST + FLIGHT VIZ	Guardian
Ease of use	x	x		x	x						x			
Automation and functionality	x	x		x			x	x	x		x	x		x
Analysis and Visualization capabilities	x	x		x	x	x	x	x	x		x	x	x	x
Customizability	x	x			x	x		x			x	x	x	
Drill-down capability	x					x						x		
Corrective actions implementation and tracking	x				x		x	x		x				
Performance monitoring and management	x	x		x	x		x	x		x		x	x	x
Safety management	x			x	x	x	x	x	x	x	x	x		x
Operations quality monitoring	x	x		x	x		x	x	x	x	x	x	x	x
Risk monitoring and analysis	x	x		x		x	x	x	x	x		x		
Analysis data export flexibility	x	x		x			x	x						
May be used for training purposes	x	x		x	x	x	x	x	x	x	x	x	x	
Information sharing	x				x			x	x		x		x	

ALERTS = Aircraft Logging and Event Recording for Training and Safety, GAU = Geospatial Awareness Unit, QAR = Quick Access Recorder, RADS = Radar Analysis Debriefing System, EMS = Event Management System

3. RISK MANAGEMENT SOFTWARE

About three-fourths of the surveyed FDM software solutions perform some sort of operational risk monitoring using flight data records. Whereas the current focus is on the use of flight data records to derive information about operational risk or safety and performance, it is also worth looking at how risk management is performed outside of FDM.

This section provides an overview of the capabilities of various risk assessment software identified in publicly available literature. Whereas some of the tools identified can apply directly to aviation FDM, most of them span a wide range of applications and industries, from banking and finance to information and security, energy and utility, oil and gas, mining, technology and telecommunications, construction and engineering, retail and distribution, transportation and logistics, government, healthcare, insurance, and manufacturing. Only an approximate fifth of the RMS software solutions surveyed mention that they have the potential to be integrated with other types of software and be used with more specific FDM software. (This observation is based on either limited information or inference from available information about the identified RMS software solutions, and is by no means definitive.) Table 4 summarizes the major characteristics of the surveyed RMS. Once again, the information provided in Table 4 has been extracted from marketing materials, such as software providers' websites, online brochures, online fact sheets, and online videos available at the time this report was written. As a consequence, there is no guarantee that the information summarized in Table 4 is accurate or represents current functionality.

Most of the RMS software solutions surveyed have at least the following capabilities:

- Repository of definitions of terms and criteria relevant to risk management
- Risk lifecycle analysis
- Gap analysis
- Incident management
- Change management
- Quality management
- Risk management system performance monitoring
- Management oversight
- Visualization of risk assessment
- Reporting of risk assessment
- Learning and sharing of experience and best practices inside the organization and with others
- Safety value creation and protection through proactive risk analysis and preventive actions monitoring
- Potential for integration with other software

The following sections provide general definitions for the aforementioned elements.

Table 4. Risk management tool capabilities summary

SOFTWARE PROVIDER	Ideagen Helicopter Solution	Logic Manager	Metric Stream	360 factors	Refinitiv® Risk Manager	Avation SMS Pro Risk	Industry Safe	Rivo	Xactium cloud solutions	Synergi Life	PRISM Safety	Q5 Systems SMS – Risk management	Mitratech Compliance RMS	EtQ RMS
DEFINITIONS														
Risk	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Threat	x		x			x	x	x			x			
Hazard	x		x			x	x	x		x	x	x		x
Risk evaluation criteria	x	x	x	x	x	x		x	x	x	x	x	x	x
Risk tolerance levels	x	x	x		x	x			x	x	x	x		x
Key risk indicators	x	x	x	x	x	x		x	x	x	x	x	x	x
Key control indicators	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Key performance indicators	x	x	x	x	x	x		x		x	x	x	x	x
RISK LIFECYCLE ANALYSIS														
Risk identification and prioritization	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Risk evaluation	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Risk assessment	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Risk mitigation	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Root-cause analysis	x	x	x		x	x	x	x	x	x		x	x	x
Impact analysis	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Risk tolerance analysis		x	x	x	x	x				x	x		x	
Multi-dimensional risk assessments	x	x	x	x	x	x			x	x	x	x	x	x

Table 4. Risk management tool capabilities summary (continued)

SOFTWARE PROVIDER	Ideagen Helicopter Solution	Logic Manager	Metric Stream	360 factors	Refinitiv® Risk Manager	Avation SMS Pro Risk	Industry Safe	Rivo	Xactium cloud solutions	Synergi Life	PRISM Safety	Q5 Systems SMS – Risk management	Mitratech Compliance RMS	EtQ RMS
GAP ANALYSIS														
Risk exposure	x	x	x	x	x	x	x	x		x	x	x	x	
Missing controls	x	x	x	x	x	x	x	x	x	x	x			
Ineffective management of risk, controls, and actions	x		x	x	x	x	x	x	x	x	x			
Notification of inappropriate actions	x			x	x	x		x	x	x	x			
INCIDENT MANAGEMENT														
Manage threats	x		x	x	x	x	x	x	x		x			
Manage risks	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Manage consequences	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Manage barriers and controls	x	x	x	x	x	x	x	x	x	x	x	x	x	X
Record incident and near-misses	x		x		x		x	x	x	x		x	x	X
Relate events, incidents and near-misses to relevant risk	x		x		x		x	x	x			x		x
CHANGE MANAGEMENT														
General view of relationships between controls and risks	x	x		x	x		x		x		x	x		x
Insight and awareness of resulting control changes on risks management	x	x		x	x					x	x	x	x	x

Table 4. Risk management tool capabilities summary (continued)

SOFTWARE PROVIDER	Ideagen Helicopter Solution	Logic Manager	Metric Stream	360 factors	Refinitiv® Risk Manager	Avation SMS Pro Risk	Industry Safe	Rivo	Xactium cloud solutions	Synergi Life	PRISM Safety	Q5 Systems SMS – Risk management	Mitratech Compliance RMS	EtQ RMS
MANAGEMENT OVERSIGHT														
Status reports	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Outstanding actions	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Overdue actions	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Alerts	x	x	x	x	x	x	x	x		x	x	x	x	x
Workflow management	x	x	x	x	x	x		x	x	x	x	x	x	x
Escalation management	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Cross-functional collaboration to facilitate investigation and resolution	x	x	x	x	x	x		x	x	x	x	x	x	x
Review of systems, processes, people at charge, and risk assessments	x	x	x	x	x	x		x	x	x	x	x	x	x
Manage access and permissions	x	x		x		x		x	x	x	x	x		
Report designer (create and add reports to library)	x	x				x		x	x	x		x		x
Customizable dashboard for gaps	x	x	x											

Table 4. Risk management tool capabilities summary (continued)

SOFTWARE PROVIDER	Ideagen Helicopter Solution	Logic Manager	Metric Stream	360 factors	Refinitiv® Risk Manager	Avation SMS Pro Risk	Industry Safe	Rivo	Xactium cloud solutions	Synergi Life	PRISM Safety	Q5 Systems SMS – Risk management	Mitratech Compliance RMS	EtQ RMS
QUALITY MANAGEMENT														
Document risks, actions, changes, status	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Document controls	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Manage audits	x	x	x	x	x	x		x	x	x	x	x	x	x
Document corrective and preventive actions	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Manage incident reporting and investigations	x	x	x	x	x	x	x	x	x		x	x	x	x
Manage analysis of findings	x	x		x							x	x		
Manage assets	x	x		x				x						
Manage employee competence and development	x			x		x	x	x		x		x	x	x
Monitor progress of risk management system		x		x	x	x			x	x				x
Manage regulatory compliance	x	x	x	x	x	x	x	x		x	x	x	x	x
Real-time quality statistics and analytics	x		x		x	x	x	x	x	x	x			x
Drill-down quality analysis	x	x	x		x	x	x	x	x					x
LEARNING AND SHARING														
Sharing of best practices (two-way)	x	x		x		x	x	x		x	x			x
Sharing of learning (two-way)	x	x	x	x		x	x	x		x	x			x

Table 4. Risk management tool capabilities summary (continued)

SOFTWARE PROVIDER	Ideagen Helicopter Solution	Logic Manager	Metric Stream	360 factors	Refinitiv® Risk Manager	Avation SMS Pro Risk	Industry Safe	Rivo	Xactium cloud solutions	Synergi Life	PRISM Safety	Q5 Systems SMS – Risk management	Mitratech Compliance RMS	EtQ RMS
VALUE CREATION (AND PROTECTION)														
Proactive risk analysis (identify contributing factors)	x	x		x	x	x	x	x			x	x	x	x
Optimize performance through risk management	x			x		x				x			x	
Preventive actions monitoring	x	x	x	x	x	x	x	x		x	x	x	x	x
PERFORMANCE MONITORING (OTHEN THAN FDM)														
Aggregate (integrate, consolidate) diverse data from various systems	x	x	x	x	x	x	x	x	x		x	x	x	x
Measure performance according to KPIs (key performance indicators)	x	x		x	x	x		x		x	x		x	
Drill-down analysis	x	x	x		x	x	x	x		x	x		x	
Monitor risk in various operational areas	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Monitor deviations (real time trend analysis)	x	x	x	x	x	x	x	x		x	x		x	x
Track corrections	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Trends and statistical analysis	x	x		x	x	x	x	x	x	x	x			x
OTHER														
Integrable with other software or tools	x	x												x

Table 4. Risk management tool capabilities summary (continued)

SOFTWARE PROVIDER	Ideagen Helicopter Solution	Logic Manager	Metric Stream	360 factors	Refinitiv® Risk Manager	Avation SMS Pro Risk	Industry Safe	Rivo	Xactium cloud solutions	Synergi Life	PRISM Safety	Q5 Systems SMS – Risk management	Mitratech Compliance RMS	EtQ RMS
VISUALIZATION OF RISK ASSESSEMENT (BOWTIE)														
Triage (partitioning and prioritizing analysis of high-throughput sequencing data)	x			x	x	x		x	x	x	x	x		x
Action tracking	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Workflows	x	x	x	x	x	x		x	x	x	x	x	x	x
Escalation alerts	x		x	x	x	x	x	x	x	x	x	x	x	x
Risk registers	x	x			x	x		x	x	x	x		x	x
Safety cases	x					x	x			x	x	x		x
Executive dashboards	x	x	x	x	x	x	x	x	x	x	x			x
Risk heat maps	x	x	x	x	x	x	x		x	x	x	x	x	x
REPORTING														
Graphs, matrices, bowties	x	x	x	x	x	x	x	x	x	x	x			x
Configurable reporting	x	x				x	x	x	x	x	x	x		x
Email notifications	x	x	x	x		x	x	x	x	x	x	x	x	x
Automatic reporting	x	x	x	x		x		x	x		x	x		x
Report builder	x	x		x	x	x		x	x			x		x
Trend report	x	x	x	x	x	x	x	x	x	x	x	x		x
Risk reporting	x	x	x	x	x	x	x	x	x	x	x	x		x
Performance reporting	x	x		x				x						
Quality reporting	x	x	x	x			x	x		x	x	x		x
Audit reporting	x	x	x	x	x	x		x	x	x	x	x	x	x

3.1 RISK LIFECYCLE ANALYSIS AND GAP ANALYSIS

To perform an accurate assessment of risk in a specific area of operations, it is first necessary to define relevant terms, evaluation criteria, and indicators. More than half of the RMS software solutions surveyed present a repository of relevant hazards, threats, and risks, and a list of risk evaluation criteria, risk tolerance levels, key risk indicators, key performance indicators, and key control indicators. A hazard is a situation or condition that may have negative consequences. A threat is the potential cause to an event that could occur if control over the hazard is lost. A risk is the assessed potential of a hazard to cause harm or damage should it precipitate into a safety event.

The risk lifecycle analysis is composed of five major components:

1) Risk identification and prioritization according to significance or likelihood
2) Risk evaluation or quantification based on predefined evaluation criteria
3) Risk assessment or classification according to predefined risk tolerance levels (can be quantitative or qualitative, and can be done by scoring or tabulating risks)
4) Risk mitigation or identification of relevant actions, risk control measures, or barriers (Correlation with past event data can be done to decide the most appropriate actions; mitigation can be avoidance, acceptance, transference, and control)
5) Risk monitoring or safety value protection (proactive risk analysis and preventive actions monitoring)

More than half of the RMS software solutions surveyed also perform various types of root cause, impact, and tolerance analyses as part of the risk lifecycle analysis process. This process can span multiple dimensions across the organization, such as operational, financial, environmental, legal, reputational, and social. However, when considering FDM, the focus is on potential tools and methods that can be transferred to the operational domain.

3.2 INCIDENT MANAGEMENT AND CHANGE MANAGEMENT

Incident management involves managing risks, threats, controls, barriers, actions, and consequences; recording incidents and near misses; and relating events, incidents, and near misses to relevant risks for a more complete picture. Incident management is directly linked to change management in that it provides a general view of relationships between controls and risks that allow determining which control(s) can be applied to more than one risk. It further provides insight into and awareness of the consequences of changing controls on the corresponding risks. Incident management is done through the use of a heat map (such as the one shown in Figure 6), which allows tracking the impacts of mitigating activities on various risks.

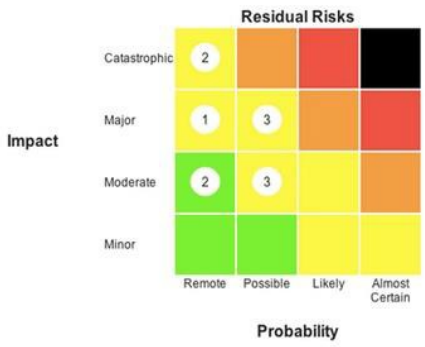

Figure 6. Example of a risk heat map [124]

3.3 QUALITY MANAGEMENT AND RISK MANAGEMENT SYSTEM PERFORMANCE MONITORING

Approximately three-fourths of the RMS software solutions surveyed are capable of providing basic quality management activities such as:

- Documenting risks, threats, and hazards
- Documenting corrective and preventive actions and control changes
- Managing incident reporting and investigation
- Managing audits
- Managing regulatory compliance

Some other software solutions also provide the ability to manage results of previous analyses for later use, manage employee competence and development, manage assets in the organization, perform real-time quality statistics and analytics (including drill-down analysis to the relevant causes of potential safety-related events), and monitor the progress of the risk management system itself.

Quality management is often associated with performance monitoring of the RMS (i.e., how efficiently and effectively the RMS is addressing risk). Approximately three-fourths of the RMS software solutions surveyed provide basic RMS performance monitoring capabilities, including:

- Aggregating (integrating and consolidating) diverse data from various systems in the organization to monitor the ability of the RMS to deal with risk in various areas (such as flight operations, ground operations, technical operations, security, overall performance, environment, finance, occupational health, and reputation)
- Monitoring deviations of the RMS from predefined targets
- Tracking the efficiency and effectiveness of the RMS to define and implement relevant mitigative/corrective/preventive actions
- Performing trend and statistical analyses to support all the above

More than half of the RMS software solutions identified also provide organizations or industries with the ability to measure RMS performance according to predefined key performance indicators, and analyze the hierarchical flow of people, actions, and other information involved in the RMS.

3.4 MANAGEMENT OVERSIGHT

Management oversight deals with all the activities enabling management to get insight into the status of various reports, outstanding actions, overdue actions, relevant systems, processes, people in charge of controlling risks, and other information that ensures business continuity. Management oversight also refers to workflow management, escalation management (how alerts are triggered and sent to executives when the management system receives no response from concerned people across the business), and cross-functional collaboration management. Management oversight involves managing the route of information to competent people across the business as appropriate, triggering and sending alerts to higher organizational levels when the management system receives no response from concerned people, and facilitating investigation and resolution of risks across the organization. Finally, some additional capabilities may include managing access and permissions of various people in the organization to deal with risk, creating and adding new reporting schemes to a report designer library, and customizing dashboards for gap analysis.

3.5 VISUALIZATION AND REPORTING

In the majority of the RMS software solutions surveyed, visualization of risk assessment is done through bowtie representations (see Figure 7), which are said to be a highly effective way of understanding and displaying threats, risks, and consequences simultaneously. Bowtie graphs also highlight relationships between barriers and controls that have been implemented to prevent incidents or limit resulting damage if and when they occur. Bowtie representations can be used to display information relating to action tracking, data workflows, escalation alters, risk registers, safety cases, and risk heat maps.

Reporting is mainly done through bowtie diagrams, matrices, and various types of graphs, including bar charts, stacked bar charts, pie charts, trending plots, scatter plots, radar plots, Pareto charts, column charts, and stacked column charts. Most RMS software solutions surveyed allow the user to manually generate reports of trends, risks, quality issues, and audits. Some others provide automatic or configurable reporting capabilities through a report-builder interface, but very few of them allow the generation of performance reports. Almost all RMS software solutions identified have some email notification capability for easy and fast reporting of urgent issues.

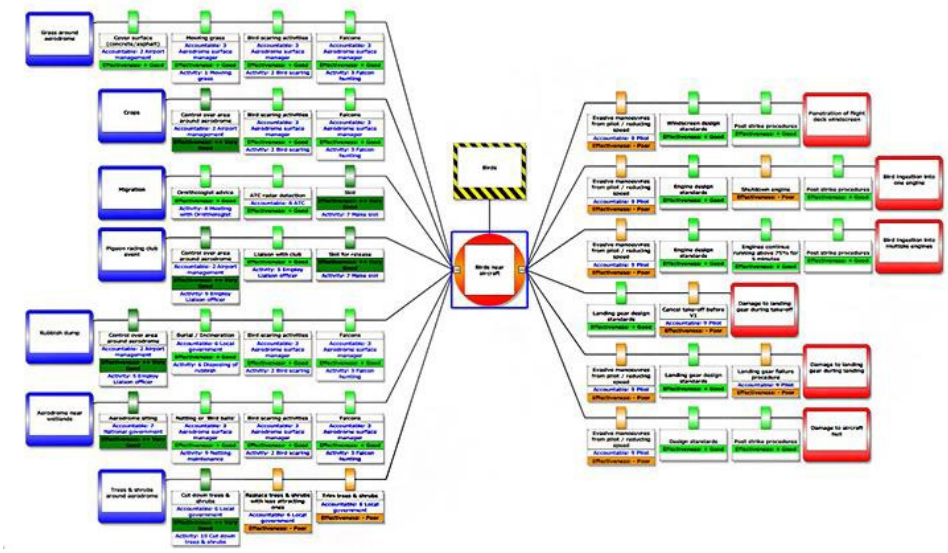

Figure 7. Example bowtie diagram [23]

3.6 GENERAL OBSERVATIONS

Based on our survey, the main requirements of a risk management system are:

- To quickly and efficiently identify where in the organization risks are present or could potentially arise
- What their potential consequences are across multiple operational areas
- What corrective or preventive actions or barriers exist or need to be put into place to mitigate them
- Who is responsible for implementing or defining those actions, controls, or barriers (workflow management)
- How risks are being handled on an organizational scale (escalation management)

Most RMS solutions use rather simple visual representations to generate and document a real-time global overview of the risk level in the organization and potential future risk areas. This task is done by aggregating various types of information and data from various types of documents, reports, or systems across the organization. Finally, it seems like most of the risk management system software solutions identified apply to rather large organizations or industries that may be composed of multiple branches, located in different states or countries and working more or less independently from one another.

In the context of HFDM for ASIAS, a risk assessment module would be of great value if it remains simple enough for relevant information to be displayed to operators so that they can concentrate on high-risk, high-occurrence events; implement and monitor appropriate corrective or preventive actions; monitor operational quality and performance; and have the means to reduce potential incidents and events before they occur. We envision that this type of proactive and preventive risk monitoring will result from the application of data mining and risk visualization techniques to FDM data. The value of RMS within FDM resides in the ability to develop and track measures to

reduce/mitigate risks, and track how such measures reduce the occurrence (or risk of occurrence) of events and deviations from SOPs.

4. SAFETY MANAGEMENT SOFTWARE

As mentioned in Section 2. , FDM addresses most parts of the last three pillars of an SMS in the operational domain: operational safety assurance, operational safety risk management, and operational safety promotion. Some information is nevertheless missing when it comes to addressing safety policy. There are also potentially useful methods and tools dealing with other types of safety assurance, safety risk management, and safety promotion in the environmental, financial, social, and legal domains. Therefore, various SMS software solutions dealing with enterprise safety as a whole have been researched to determine a set of capabilities that may be valuable for FDM. This survey is based on information found in publicly available literature. Whereas some of the SMS capabilities identified can apply directly to aviation FDM, most of them span a wide range of applications and industries. Almost all of the SMS software solutions surveyed present a counterpart in the domain of ERM because this is an integral part of an efficient SMS. Table 5 summarizes the major characteristics of the surveyed safety management software solutions. Once again, the information provided in table 5 has been extracted from marketing materials, such as software providers' websites, online brochures, online fact sheets, and online videos available at the time this report was written. As a consequence, there is no guarantee that the information summarized in Table 5 is accurate or represents current functionality.

An enterprise safety management tool is generally composed of:

- Safety policy
- Safety assurance (including basic proactive and predictive quality management and performance management)
- Safety promotion and training
- Risk management

As mentioned already, FDM addresses only the operational part of safety assurance, safety risk management, and safety promotion. It does not consider safety policy, at least not explicitly, or this was not obvious from our survey of FDM software solutions performed in Section 2. .

Table 5. Safety management tool capabilities summary

SOFTWARE PROVIDER	Ideagen Q-Pulse®	Aviation SMS Pro	AeroSDB	Intelex	Galilot	Industry Safe	Rivo	Universal Weather & Aviation	Synergi Life	Q5 Systems SMS	Avinet	Mitratech SMS	EtQ SMS
SAFETY POLICY													
Organizational chart		x		x	x	x		x		x	x		
Duties and requirements	x	x		x	x	x	x	x	x	x		x	
Safety performance metrics	x	x		x	x	x	x			x			x
Implementation manager	x	x		x	x		x	x		x	x		x
Applicable manuals	x	x		x		x	x	x	x	x	x	x	
Applicable regulations	x	x		x	x	x	x	x	x	x	x	x	
Policies and procedures	x	x		x	x		x	x	x	x	x	x	
Documents manager	x	x		x	x		x	x		x	x	x	x
SAFETY ASSURANCE													
Qualifications and training		x		x	x	x	x		x	x	x	x	x
Audit form manager	x	x		x	x		x	x	x	x	x	x	x
Audit scheduler	x	x		x	x		x	x	x	x	x	x	x
Gap analysis	x	x		x	x	x	x	x					
Risk exposure	x	x	x	x	x	x	x	x	x	x		x	x
Issue validation	x	x	x	x	x	x	x	x		x		x	x
Predictive analysis tool	x	x	x	x	x		x	x		x		x	x
Process library		x		x				x	x				
Compliance manager	x	x		x	x	x	x	x	x	x	x	x	x
Proactive safety management	x	x	x	x	x	x	x	x		x	x	x	x
Predictive safety management	x	x	x	x	x	x	x	x		x	x	x	x

Quality management	x	x		x		x	x		x	x	x		x
Performance monitoring	x	x		x	x	x	x	x	x		x	x	x

Table 5. Safety management tool capabilities summary (continued)

SOFTWARE PROVIDER	Ideagen Q-Pulse®	Aviation SMS Pro	AeroSD B	Intelex	Galilot	Industry Safe	Rivo	Universal Weather & Aviation	Synergi Life	Q5 Systems SMS	Avinet	Mitratech SMS	EtQ SMS
SAFETY PROMOTION/TRAINING													
Safety report	x	x	x	x	x	x	x	x		x	x		
Safety statistics	x	x				x	x	x			x		x
Meeting manager		x		x	x	x	x	x				x	x
All employee letter	x	x			x			x					
Message board	x	x			x	x		x		x			
General issue viewer	x	x		x	x	x	x	x		x		x	x
Lessons learned library		x		x	x	x	x	x		x			x
Document employee SMS role and understanding	x	x		x	x	x	x					x	
Training manager				x	x	x	x	x		x	x	x	x
RISK MANAGEMENT													
Issue manager	x	x	x	x	x	x	x	x	x	x		x	x
Hazard and risk registry	x	x	x	x	x	x	x	x	x	x	x	x	x
Proactive hazard analysis	x	x	x	x	x	x	x	x		x	x	x	x
Risk analysis charts	x	x	x	x	x	x	x	x	x	x	x	x	x
Data analysis and export	x	x	x	x	x	x	x	x	x	x	x	x	x
Trending charts	x	x	x	x	x	x	x	x	x	x	x	x	x
Management of change	x	x		x	x			x	x	x		x	x
Corrective actions manager	x	x	x	x	x	x	x	x	x	x	x	x	x
Financial risk analysis charts		x						x		x			

4.1 SAFETY POLICY

It is the responsibility of the leadership of an organization to establish its safety policy.The safety policy component of an SMS defines senior management's commitment to continually improve safety. It sets the methods, processes, and organizational structure needed to establish standards and meet safety goals. Its design expectations are to continually improve the level of safety, comply with applicable regulatory requirements, establish clear standards for acceptable operational behavior for all employees, and identify responsibility and accountability of management and employees with respect to safety performance. Workflow and implementation tools allow the right people to access, create, modify, review, and approve policy documents, and to facilitate the acceptance, exception tracking, and management of change related to policy distribution.

The safety policy component of an SMS further consists in maintaining an accurate and accessible inventory of all safety-related documents to support the management, enforcement, and monitoring of compliance across the organization. This component includes keeping track of all applicable manuals, standards, guidelines, regulations, policies, procedures, reporting obligations, and business-specific safety performance metrics.

Many safety professionals believe that all accidents are preventable, that injuries to employees and others in the workplace are avoidable, and that any harm to the environment is intolerable. Safety has to be treated as a core value. This can be achieved through awareness, training, incentives, and a strong focus on proactive efforts relative to safety management, which includes FDM.

SMS is a decision-makers' program, and FDM should be a part of that decision-making process. Operators, large or small, should take a closer look at the SMS process and FDM, and should incorporate a "Just Culture" into every flight. Safety policy must bring the safety effort into a normal management framework, which includes FDM. A good safety policy provides the means to show evidence of effective policy implementation to management, regulators, auditors, and other stakeholders. Without good leadership and an effective safety policy, using FDM as a safety tool will not take place.

4.2 SAFETY ASSURANCE

The safety assurance component of an SMS consists of several modules dealing with audit and inspection management, identification of new hazards, and effective implementation of risk control strategies, performance monitoring, compliance management, and development of methods for improving safety and minimizing risks. The goal is for management to identify and manage hazards and quality of operations, customize and manage internal audit forms, and efficiently plan and process audits. This component also provides a means to conduct regular gap analysis with respect to regulatory standards to monitor quality and process improvement, and to proactively analyze both current and historical facts to forecast potential future events. This allows management to continuously monitor the performance of the SMS program and to schedule, track and report on employee training, licensing, certifications, qualifications, roles, and positions with respect to safety.

4.3 SAFETY PROMOTION AND TRAINING

The safety promotion and training component of an SMS consists of various types of reports, newsletters, message boards, libraries, and email notifications sent automatically or by management to all employees in the organization to promote safety, to address safety issues and to provide safety statistics. This component also enables management to prove and document relevant employee training and understanding of their SMS roles. This allows management and employees to search for and review past lessons learned from safety issues and either missing, inefficient, or inappropriate actions.

4.4 RISK MANAGEMENT

The risk management component of an SMS is designed to help organizations proactively manage risks and hazards, promote a widespread understanding of all risks across the organization, manage the effectiveness of controls and corrective actions in place, understand the impact and extent of changes to controls, and share lessons learned and best practices across the entire organization. The goal is to facilitate the identification, assessment, monitoring, and mitigation of both existing and potential risks within the organization. This task includes tracking risks and hazards, analyzing trends, managing the efficiency and adequacy of established corrective and preventive actions, and managing the effects of changing controls on the probability and consequences of corresponding risks.

4.5 GENERAL OBSERVATIONS

Based on our survey, most of the functionalities provided by an SMS are designed to ensure compliance with policies, regulations, standards, and procedures; to monitor quality of operations and employee compliance with required safety training and responsibilities; and deal with risk affecting the whole organization. It is worth noting that a majority of the SMSs have a well-developed risk management module with useful capabilities for FDM, as previously mentioned when dealing with RMS.

Most of the SMS software solutions identified apply primarily to large organizations or industries that may be composed of multiple branches, located in different states or countries and working more or less independently from one another. As a consequence, for small rotorcraft operators similar to those that may get involved in R-ASIAS, a simpler version of the rather sophisticated SMS software solutions identified in this survey may be more appropriate.

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APPENDIX A—OPERATIONAL SAFETY TOOLS DESCRIPTIONS

Aerobytes Flight Data Monitoring

Aerobytes Flight Data Monitoring (FDM) software delivers the following features and abilities [3]:

- Automate routine tasks associated with flight data analysis
- Go into the details of flight data analysis (i.e., from events and associated severity to triggers or items contributing to events, to flight data corresponding to events), and identify relevant parameters leading to an event
- Overlay corrective/remedial actions directly on statistical reports to see their effects (quality assurance tools)
- Share data with other safety software products for a bigger picture of the safety, quality, and performance environment (SMS software integration)

> "The Aerobytes FDM system is particularly well suited to the rotary wing environment which frequently has far more complicated operational envelopes and constraints than those employed for airliners. The system is able to apply 'context' (time of day, rig / ship-based / ground-based, headwind component, etc) when analysing flights so that results are reliable. The system warns of potentially dangerous and helicopter-specific situations such as control inputs that could have led to a dynamic rollover. Transition phases are also closely monitored to ensure optimum, consistent and safe performance." [3]

Figure A-1 displays some examples of flight replay and animations provided by the Aerobytes FDM software.

Figure A-1. Flight replay and animations from Aerobytes FDM software

Appaero Systems: ALERTS

Appareo Systems Aircraft Logging and Event Recording for Training and Safety (ALERTS) is a Flight Operational Quality Assurance (FOQA) application designed to work with the corresponding ALERTS hardware developed by Appareo, such as the Appareo Vision 1000, the Appareo Geospatial Awareness Unit (GAU) 2000, the Appareo Transfer and Playback Utilities, and the AS Flight Analysis Software and Web Analyzer Software [7].

The Appareo Vision 1000 is a low-cost, lightweight, and minimally intrusive device combining flight data recording, cockpit imaging, and audio recording. It captures inertial and positioning parameters – such as location, altitude, and acceleration – and audio and cockpit video of instrument panels, flight controls, and partial exterior view. The data are stored both on a memory module and on a removable SD card for easy transfer through the Appareo Transfer Utility to Appareo's ALERTS servers.

The Appareo GAU 2000 is a low-cost and lightweight versatile data recorder featuring a suite of sensors, such as accelerometers, gyros, magnetic and pressure sensors, and a GPS module that

enable it to record a wide variety of motion data. The data are stored both on a crash-hardened memory module and on a removable SD card for easy analysis.

The Appareo AS Flight Analysis Software allows rotorcraft operators to replay individual flights in a realistic 3D environment. It uses the Appareo Playback Utility to display the video and audio captured by the Appareo Vision 1000 device during the replayed flight, and the Appareo worldwide terrain to render rich and accurate representations of the corresponding terrain encountered during the recorded flight. The Appareo three arc-second terrain database was developed from terrain data obtained from the NASA Shuttle Radar Topography Mission (SRTM), in which missing critical terrain features are identified and rectified by proprietary void-filling algorithms. Figure A-2 provides examples of 3D and 2D analysis tools from Appareo AS Flight Analysis Software. Although it has been designed to work with Appaero hardware, the AS Flight Analysis Software is also compatible with some commercially available GPS receivers.

Figure A-2. 3D and 2D analysis tools from Appareo AS flight software and playback utility

The AS Web Analyzer Software is a customizable web-based application that can be used by a wide variety of rotorcraft operators to manage the activities of their fleets. Depending on the company's standard operating procedures (SOPs), the user can program any criteria or guideline into the analysis program from pre-defined, pull-down options and user-defined inputs. For instance, users can specify event triggers, identify dangerous trends, and identify flights of interest. The AS Web Analyzer Software also allows users to create fleet performance reports to identify areas of concern, issue safety briefs, and improve general safety of operations. Figure A-3 shows one of the Appareo AS Web Analyzer Software interfaces and an example bar graph representing fleet performance.

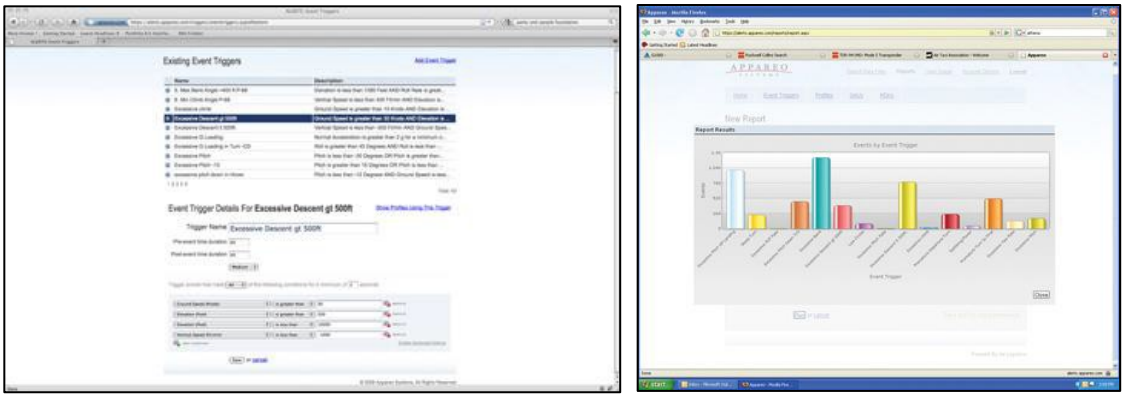


Figure A-3. Appareo AS web analyzer software

Airbus-Navblue: AirFASE®

AirFASE is a Flight Operations Monitoring (FOM) tool designed to perform all the major functions of the Flight Data Monitoring (FDM) process including, but not limited to, the following [5]:

- Flight data validation and events detection with integrated tools
- Time-efficient flight data analysis, report, and trending
- Information review with advanced graphical and 3D animation tools
- Risk assessment
- Training support through tracking and improvement of SOPs

AirFASE is also advertised as a way to help operators in:

- Preventing incidents and accidents through risk recognition and informed decision making
- Developing better knowledge of operational issues such as events and exceedances
- Optimizing crew training
- Monitoring engine health
- Lowering maintenance costs by detecting problems early
- Monitoring airframe structural health by identifying hard landings and flap over-speed deployments
- Reducing fuel consumption by detecting over-speed and out-of-trim conditions
- Monitoring brake use by identifying over-speed and unstable approaches

AirFASE is composed of several modules, each having a specific role in the FDM process:

- The AirFASE Transcription Program accurately decodes raw flight data and translates them into engineering units.
- The AirFASE Flight Analysis Program (FAP) enables the efficient processing and analysis of flight data records. It is combined with the AirFASE Reporting Module, which allows for the creation of comprehensive and customizable reports for a wide variety of

aircraft operators. Some main features of AirFASE FAP and Reporting Module include but are not limited to:

- Comparison of recorded data with recommended values
- Identification and validation of abnormal events and exceedances
- Display of flight data and events in numerical or graphical formats
- Display of flight path and parameter exceedances in color-coded graphics
- Statistical analysis of events
- Categorization of events based on their level of severity
- Automatic generation of various types of reports, such as standard, statistical, trend, and custom
- Data export to other software applications

Figure A-4 shows some examples of graphical user interfaces for flight data processing, analysis, and reporting.

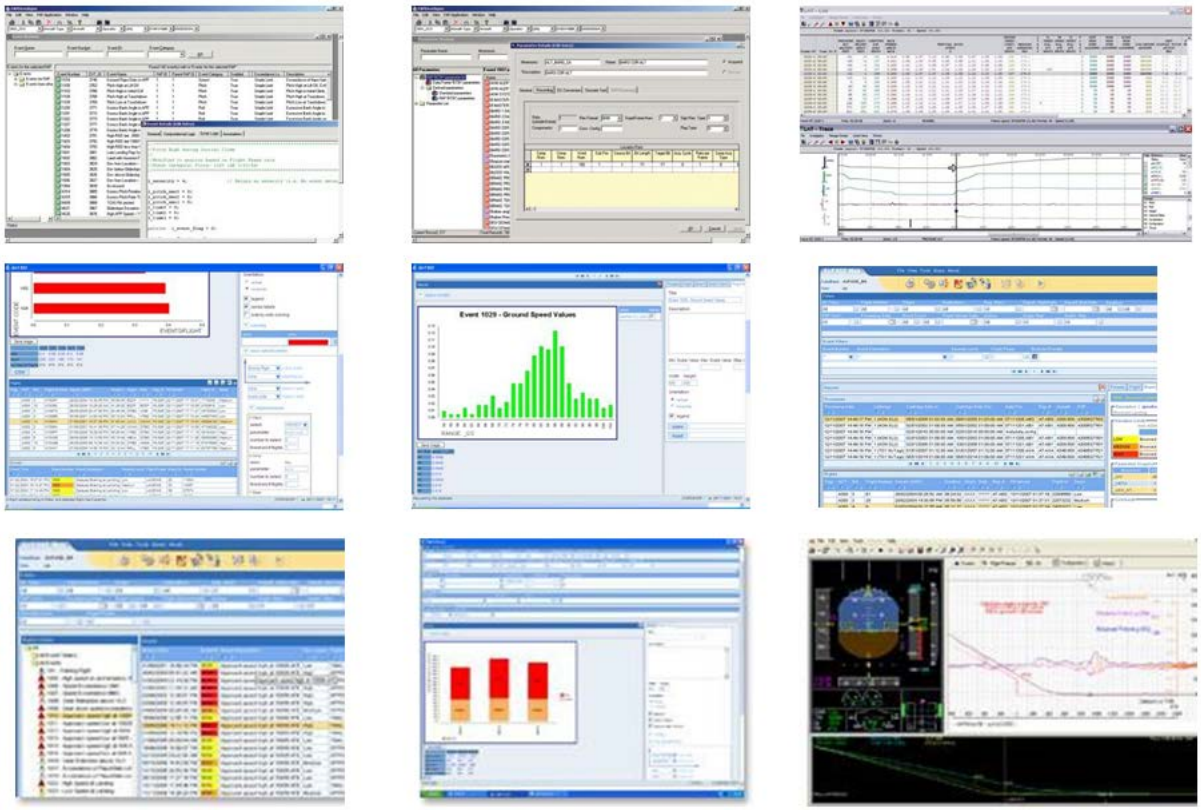


Figure A-4. AirFASE reports and displays for flight data processing, analysis, and reporting

- AirFASE visualization tools enable the 3D replay and review of flight data records to evaluate flight operations, identify risk precursors, and make informed decisions about potential preventive measures or corrective actions. Some features include:

- Cockpit instruments display
- Interactive 360° 3D animation of the aircraft and its environment with zoom and flight path trace views
- Special close-up for critical flight phases
- Manual replay with play, pause, forward, and back functions
- Synchronization of animation with graphs

Figure A-5 provides some examples of 3D animations and 2D displays from AirFASE visualization tools.

Figure A-5. 3D animations and 2D displays from AirFASE visualization tools

Some of the key features of the AirFASE flight animation package include:

- Quick view
  - Preview flight data output
  - Analyze quality of flight
  - Visualize complex operational scenarios
  - Identify areas of improvement in operating procedures and training
  - Gain insight into event or incident triggers and interrelationships
- Flight path reconstruction and correction tools
  - Make corrections to flight path
  - Refine flight path animation
  - Include additional parameters not recorded
- 3D window, animation controls and features

  - Insert and modify visual components (such as aircraft models, high resolution satellite imagery, accurate terrain and runway models, and custom models)
  - Select visual scene elements (such as ground contact module, moving aircraft surfaces, variable visibility, time-of-day options with ground shadow display, flight path display options)
  - Control replay with DVD-like controls (such as forward, rewind, pause, speed up/down, zoom in/out, observer viewing position and perspective)
  - Save and later recall multi-window screen layouts
  - Output animation in Super Video Home System (S-VHS) video and mpeg files

- 2D windows and visualization

  - Select single or multiple screens to display information
  - Experience color-coded displays (changing states within the data)
  - Integrate and over-plot aircraft position on various types of charts, maps, or plots (such as operator maps, approach plates, glide slope plot, localizer plot)

- Virtual flight deck

  - Display operators' flight deck elements (such as instruments, flight displays, flight controls, power quadrant)

- AVI movie file output

  - Review incidents
  - Write safety reports
  - Prepare briefings and presentations
  - Share reconstructed events

- Distance measuring tools

  - Measure distances in the 3D modeling environment accurately (such as runway landing distance, runway distance consumed during flare, braking distance, takeoff distance, deviation from runway centerline)

- Audio playback

  - Insert and synchronize audio data (WMV file format) within the animation (flight deck aural audio, cockpit audio, cockpit voice recorder (CVR), and ATC)

- Comprehensive online help, tutorials and training
- Compatibility with all the DFDRs and Quick Access Recorders (QARs) present on the current market

GE Aviation: Event Measurement System (EMS)

GE Aviation EMS is a software suite designed to perform flight data analysis through the use of two main solutions: the eFOQA and C-FOQA (Corporate-FOQA) Centerline™ [49],[50]. Figure A-6 shows the GE Aviation EMS interface. GE Aviation EMS provides the following capabilities:

- Data capture and transmission from aircraft (through wireless, encryption)
- Automated transcription and initial analysis of flight data
- Granular security and configurable access rights
- Data validation
- Event detection, verification, modification, and disposition tracking
- Risk identification and management (lowest frequency, highest severity events monitoring using high-quality, large aggregated datasets)
- Alerting of high-risk occurrences (event severity assignment and review)
- Routine reporting of flight events through statistical reports
- Dissemination of incidents and events to interested parties
- Measurement-based trends and distributions
- Parameter analysis of single flights
- Automatic trajectory correction
- Distributed processing
- Compatibility with major animation programs
- Visualization and multi-source analysis of navigational data
- Inclusion of METAR weather data at takeoff and landing sites
- Data mining and retrospective analysis of flight data (data archiving and reprocessing)
- Training optimization
- Maintenance and engineering studies
- Trending and troubleshooting
- Fuel, tire, brake monitoring

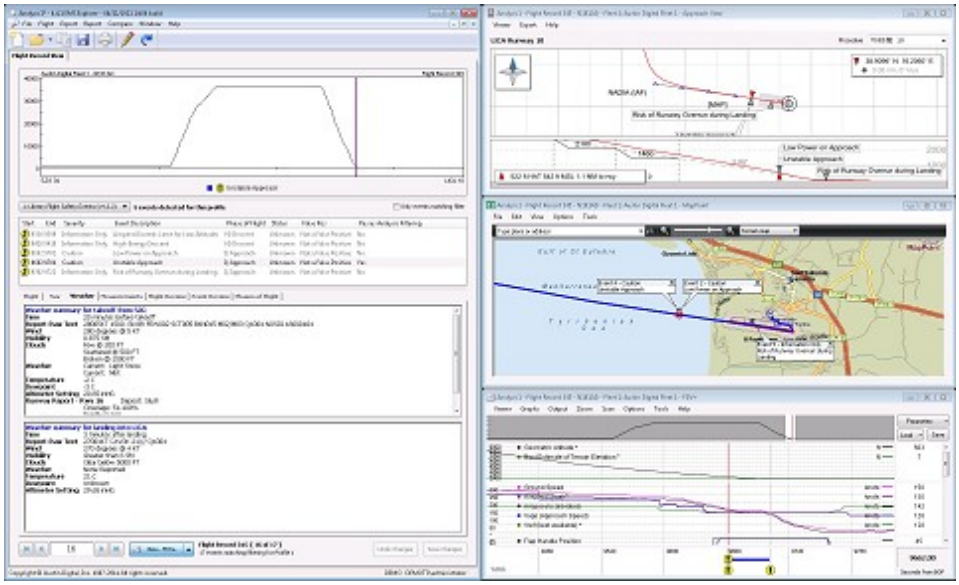


Figure A-6. GE Aviation EMS

CAE Flightscape Tool Suite: Insight™

CAE Flightscape [13] Insight integrated software suite is designed to perform flight data analysis, animation, ad reporting, safety risk analysis, flight operations economic analysis, flight de-brief, and evidence-based training. It is composed of five different modules, namely Insight FDM [15], Insight Animation [16], Insight Analysis [14], Insight Recovery [18], and Insight View/Proview [17].

Insight FDM

Insight FDM has been designed for airline FDM programs. It is used to operate the International Air Transport Association's web-based flight data analysis service. It uses a standard open architecture database, which allows the integration of various statistical tools and databases. Figure A-7 shows various screenshots from the Insight FDM tool (in Figure A-7: (a) data explorer; (b) event definition editor; (c) report of events per 100 flights; and (d) report of flight duration vs. weight).

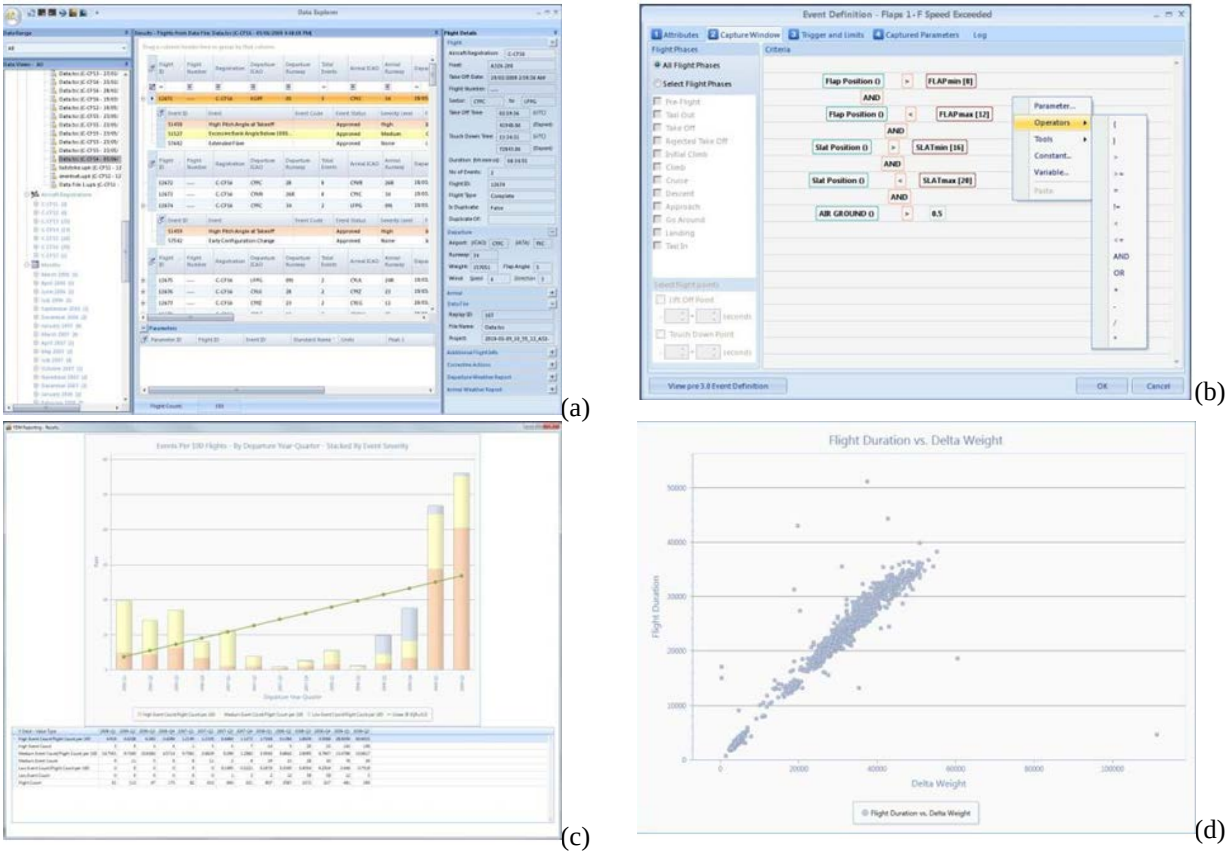


Figure A-7. CAE Flightscape Insight FDM

Insight™ Animation using Insight™ View or Insight™ ProView, and RADS

"Insight™ Animation is a comprehensive, interactive real-time flight animation system that includes Automatic Data Generation, allowing flight animations to be created automatically. It features an extensive library of panels, instruments, 3D aircraft models, a Runway Model Editor; and a 3D World Terrain Database that provides 1 km resolution terrain elevation data and satellite imagery. Users are able to build their own instruments and Electronic Flight Information System (EFIS) displays without programming." [16]

Playback animations produced through Insight Animation are displayed by either one of the freely distributable viewers Insight View or Insight ProView.

Insight Animation uses CAE Flightscape Radar Analysis Debriefing System (RADS) to display flight surveillance data in a three-dimensional environment. RADS provides the users with detailed insight into complex air occurrences through realistic animations of accidents, incidents, or other types of air events by synchronizing flight replay in space and time with ATC voice recordings and ATC transcripts. RADS also allows users to select desired radar data, aircraft data, 3D terrain data, and audio or text data through the RADS wizard interface and to save animations as video files that can be replayed at later times. "RADS incorporates the latest in airborne surveillance technology including multilateration and ADS-B[1]" [18]. It provides multiple benefits, such as:

- Flight data animation
- Incident level analysis
- Display of "what happened" and "why it happened"
- Improvement of operational, legal, and corporate decision making
- Debriefing tool for air crew and controllers

Figure A-8 shows an example 3D flight replay for an Agusta Westland AW139 and the RADS environment and wizard.

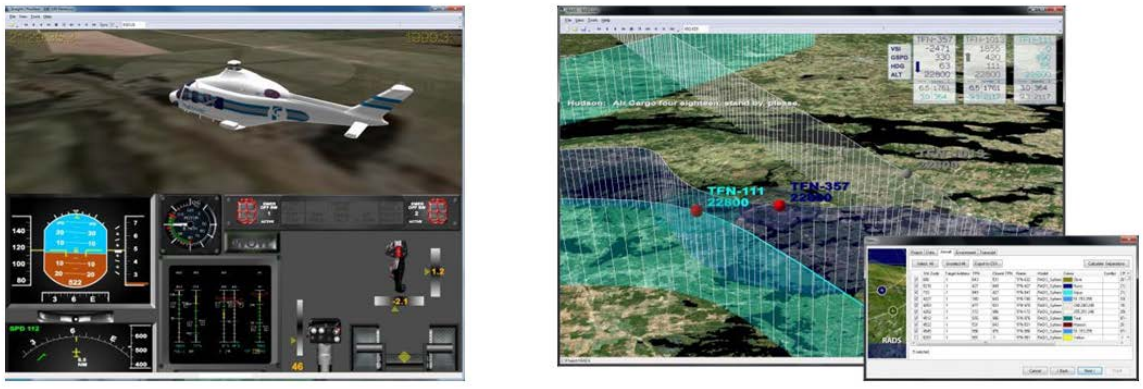


Figure A-8. CAE Flightscape Insight animation with RADS

[1] ADS-B is Automatic Dependent Surveillance-Broadcast

Insight Analysis

Insight Analysis offers a wide array of mathematical functions, and plotting and curve-fitting capabilities that allow users to study complex events and to perform various types of analyses on selected aircraft parameters.

Figure A-9 shows various screenshots from the Insight Analysis tool: (a) parameter explorer; (b) parameter analysis; (c) mathematical functions; and (d) FFD editor.

Figure A-9. CAE Flightscape Insight analysis

CAPACG: FlyteAnalytics™

FlyteAnalytics is a suite of cloud-based tools designed to provide operators of both advanced cockpit aircraft and legacy recorder-equipped aircraft a "proactive, robust, and cost-effective" FDM solution. It allows operators to "improve maintenance, operations, safety and training and provide opportunities to improve economic efficiencies while enhancing visibility into all areas of […] flight operations" [19].

FlyteAnalytics has been developed to provide safety assurance, continuous improvement of operations, and financial benefit to various types of operators. Its cost depends on the level of service and the operator's FDM needs. The baseline service is composed of a fully functional, self-managed FDM solution. The CAPACG managed solution provides a complete FDM service to operators willing to develop, implement, and manage their own FDM program on a daily basis.

The hybrid program enables operators to manage their day-to-day operation and CAPACG to manage the analysis and reporting activities [20].

Some major benefits of FlyteAnalytics include:

- Automatic FDM Fleet Aggregate summary and Aircraft Health and Maintenance (AHM) fleet aggregate summary

  - Dashboard view of events
  - Dashboard view of aircraft health and maintenance
  - Atypical flights identification
  - Event classification
  - Report of average exceedances during triggered events
  - Percentage of all events displayed
  - Summary of flight hours and rates of events
  - Maintenance monitoring

- Event details

  - Complete list of FDM and AHM events
  - Details include aircraft ID, date, duration, minimum, maximum, average values of exceedances, event ID, flight routing
  - High-level details of analyzed events

- Aircraft detail report

  - Total event by type
  - Airframe specific events
  - Event trending and monitoring
  - Exceedances relative to time for maintenance and engineering troubleshooting

- Data mining

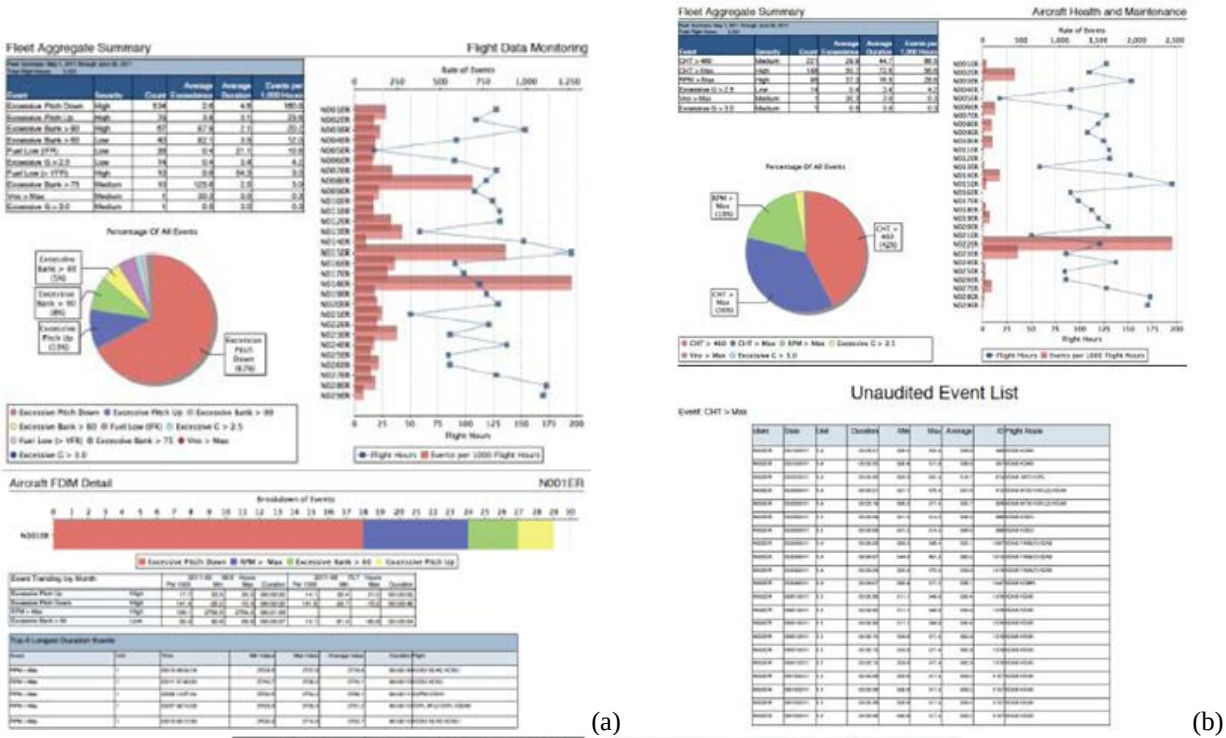
  - Training improvement
  - Fuel usage monitoring
  - Reduction of maintenance troubleshooting
  - Insight into daily operations
  - Flight activities monitoring (adherence to SOPs)
  - Asset tracking and monitoring

- Export capabilities to commercial data-processing applications, such as:

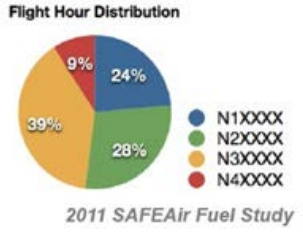
  - Google Earth™ [53], a terrain database that can be used for flight-path visualization
  - X Plane [127], a flight simulator used for 3D animations

- DataPlot®, a "free, public-domain, multi-platform […] software system for scientific visualization, statistical analysis, and non-linear modeling" [81].

Figure A-10 provides a view of various capabilities of CAPACG FlyteAnalytics: (a) FDM fleet aggregate summary; (b) aircraft health and maintenance fleet aggregate summary and event details with complete listing of all FDM and AHM events; and (c) fuel usage case study.



Data Analysis	TOTAL	Percent of Total Flights
Flight Monitored	410	100
Valid Flights	384	93.66
Valid Flights with Hi Burn	176	42.93



Fuel Analysis (2 Month Period)	Results* (GPH unless specified)
Actual Burn (average/hour)	19.018
Max Economy Burn (calculated/ hour)	17.22
Delta (Actual - Max Economy)	1.798
Average Extra Fuel/Flight	1.46 gallons
Total Extra Fuel/Study - the 4 monitored aircraft	255.63 gallons
Total Extra Fuel Cost ($5.99/gallon) - the 4 monitored aircraft	$1,531.22
Total Extra Fuel/Study (projected) - All of SAVEair aircraft (30 total)	1917.2 gallons
Total Extra Fuel Cost ($5.99/gallon) - All of SAVEair aircraft (30 total)	$11,484.18

(c)

Figure A-10. CAPACG FlyteAnalytics

Ergoss FDM & Analysis Software: SARA

Ergoss provides several tools and services for flight data analysis, including FDM, FOQA, Helicopter Flight Data Monitoring (HFDM), Maintenance Operations Quality Assurance (MOQA), flight investigation, and environmental challenges analysis, such as fuel reduction

programs, CO_2 emissions monitoring, and noise abatement compliance monitoring. SARA by Ergoss is a combination of web-based FDM tools designed to "automatically point[s] out flights of interests, emerging adverse trends while also constantly monitoring your KPI's and corrective actions thanks to unique reporting tools and user- customizable dashboards" [28]. SARA by Ergoss is composed of four main features [29].

- Personalized dashboards – This feature allows users to:
  - Display key information and indicators of interest
  - Validate and classify events and flights of interest using their own taxonomy
  - Investigate their data and reuse past analyses and results on specific events or flights of interest
  - Navigate their data using various types of filters
- Flight view – This feature provides users with the ability to:
  - Display the full set of parameters for a given flight
  - Interactively and dynamically display parameter traces, tabular data, flight profile, pilot flight deck, and instruments using Google Earth and any native 3D animation
  - Analyze parameter envelopes that compare the behavior of a given parameter from a single flight against hundreds of others
- Trends and statistics – This feature allows users to analyze events in detail and generate reports
- Risk monitoring, Key Performance Indices (KPIs) and corrective actions – This feature provides users with the ability to:
  - Define their own KPIs
  - Log their corrective actions for events of interest
  - Follow and monitor the effectiveness of their corrective actions and that of others, and share suggestions or concerns with others in the organization
  - Generate reports on corrective action effects to share with everyone in the organization

Ergoss claims that SARA is the only flight data analysis (FDA) software that provides users with the ability to perform real-time "what-if" analyses on flight data (i.e. dynamic computations of various scenarios corresponding to different parameter settings) without the need to reprocess all the data from the beginning.

SARA is 100% web-based, which allows users to access their data from anywhere at any time. It is automatically maintained and updated when necessary. It is typically hosted by Microsoft® Azure Cloud which allows for fast and secure data processing and delivery, but can also be locally installed in a private cloud. SARA "relies on MS SQL Server with views on the database that ensures that any changes to the database from one version of SARA to another will not affect any interfaces […] [that] may have [been] built to access its data." SARA can work with other software

designed to monitor aircraft and fuel usage, and can also be integrated in a SMS software. Finally, SARA has the ability to be used as a plugin with most current FDA systems [30].

Ergoss is planning on releasing two new versions of the SARA software that would provide FDA analysts with additional features for dealing with geo-referenced data (enabled by the inclusion and interpretation of navigation data officially available from Aeronautical Information Publications AIP) and for flight replay (for training purposes) [31].

Figure A-11 provides some example snapshots for data analysis and flight replay using the Ergoss FDA software SARA.

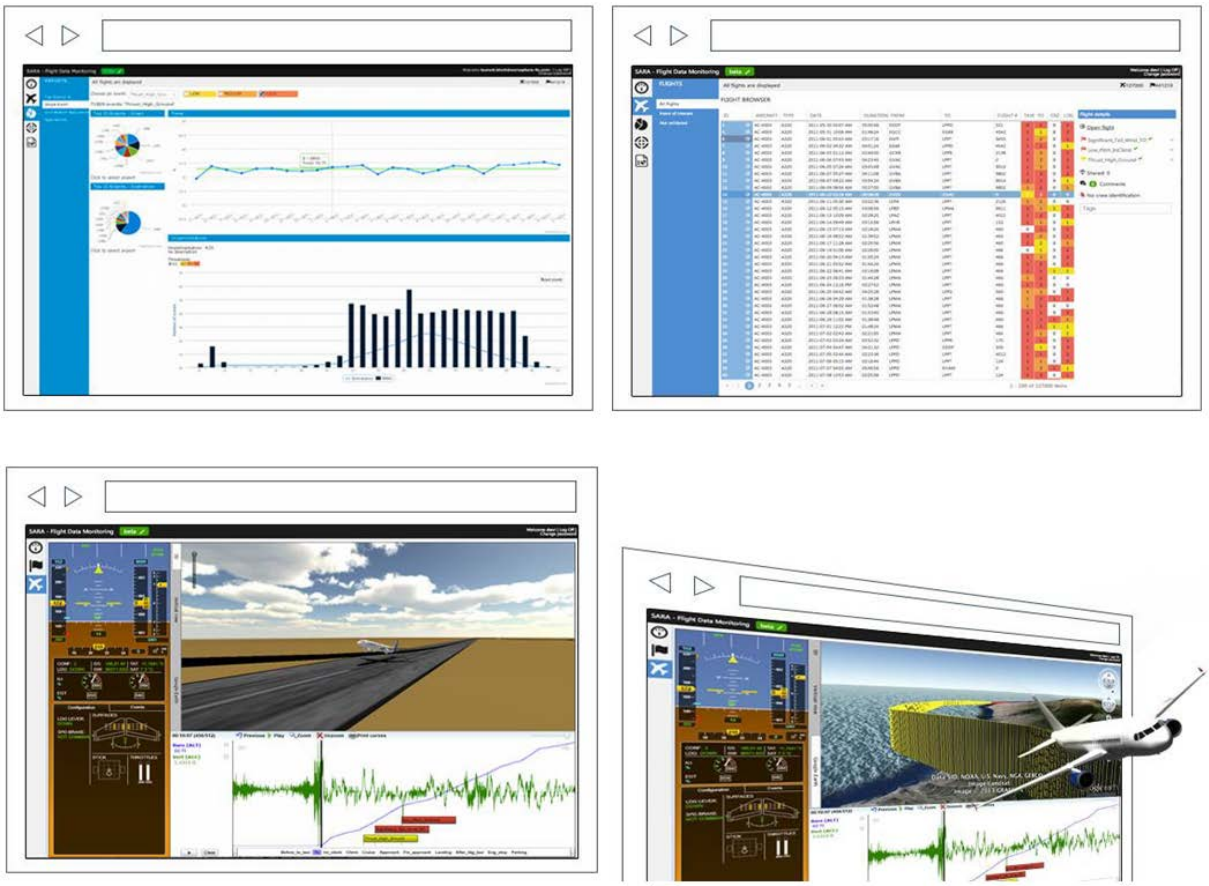


Figure A-11. SARA by Ergoss

Flight Data People: FDM360

Flight Data People (FDP) FDM360 cloud-based flight monitoring solution uses software developed by British Airways approximately 40 years ago [42]. Since then, it has been refined to accommodate new regulations and FDM requirements. As such, it is mostly geared towards commercial airline operations. According to its Sales and Marketing Director, FDP partners with RTI forensics to sometimes supply RTI with flight data simulations for aircraft accident

investigations, which are RTI's core business [99]. Most of the information regarding FDM360 was collected from a white paper provided by the Sales and Marketing Director at FDP.

The FDM360 software is composed of three main modules and one optional module. The Flight Data Traces (FDT) module features "preloaded aircraft usage charts, multi-level definitions of constants and settings, multi-event database support, system audit and configurable ops data format." The Flight Data Events (FDE) module allow detected events to be validated and analyzed in detail by frequency, severity, and rate. The Flight Data Simulations (FDS) module is used to visualize flights and events using the data collected and stored by the FDT module. Finally, the optional FDM360 Measurements module can be used to perform statistical analyses (across fleets, time periods, or airfields) on large amounts of data stored by the FDT module. Results can be displayed in the form of histograms or summary tables that can be printed, copied, and pasted into a report.

The FDP FDM360 software has the following main characteristics:

- Secure data download
- Routine processing of flight data for:
    - Traces
    - Event detection
    - Measurements capture
    - Data extractions
    - Simulations
    - Geographic analysis (using Google Maps™ and/or Google Earth)
- Flight data analysis and reporting for:
    - Filtering and grouping of flights and events
    - Events monitoring
    - Collection and display of routine parameters from all flights
    - Capture of false-alarms
    - Automatic email alerting
    - Manual and automatic emailing
    - Configurable reports
- Secure access to analysis results
- Interfaces for weather and other data
- Aircraft usage and data capture statistics
- Flexible, built-in tools for results visualization and results analysis and trending, including drill-down capability for in-depth event analysis, such as:
    - Fleet specific simulations
    - 3D simulations with integrated data from ATC, CVR, charts, instrumentation
        - Incident analysis
        - Route briefing
        - Training

The following figures feature information taken from both the RTI forensics website and the FDP FDM360 white paper. Figure A-12 shows examples of visualization available through the FDM360 software for data upload and validation, and for crew training monitoring. Figure A-13 shows graphical user interfaces for event detection and event investigation using the FDP's FDE tools. Figure A-14 shows examples of flight parameters time series and an aircraft usage chart obtained using the FDP Flight Data Traces (FDT) tool. Figure A-15 shows examples of interfaces for data export and report generation. Figure A-16 shows examples of cockpit instrumentation animation and 3D flight simulation rendered through the RTI 720° Smart Animation™ [99] software and through the FDP Flight Data Simulations tools. Finally, Figure A-17 shows an example of statistical analysis on the calibrated airspeed 8 nautical miles before touchdown using the FDM360 Measurements module.

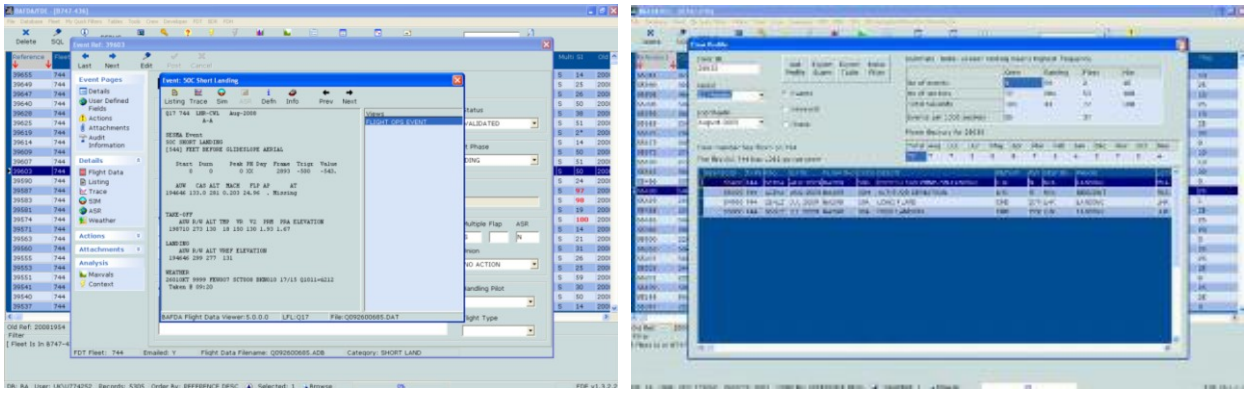


Figure A-12. FDP FDM360 – Data upload and training monitoring

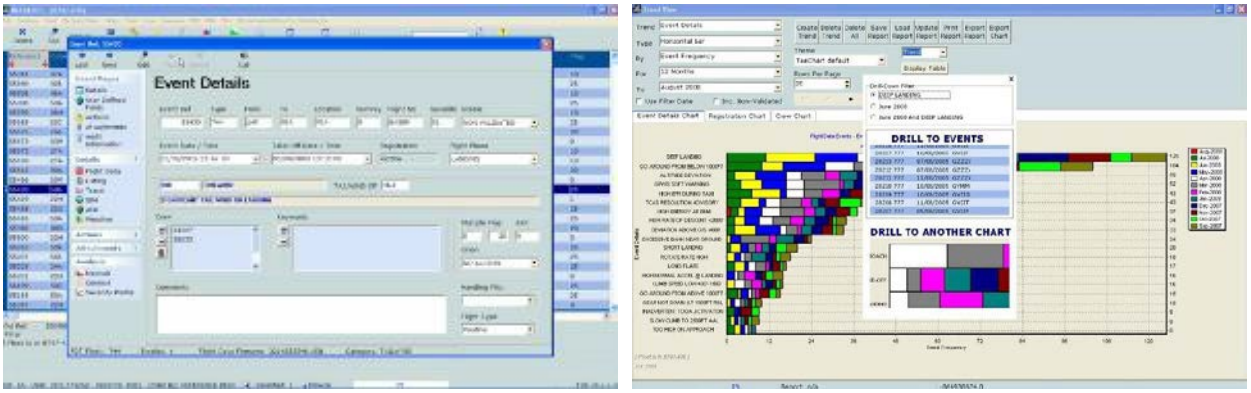


Figure A-13. FDP FDM360 – Event detection and investigation

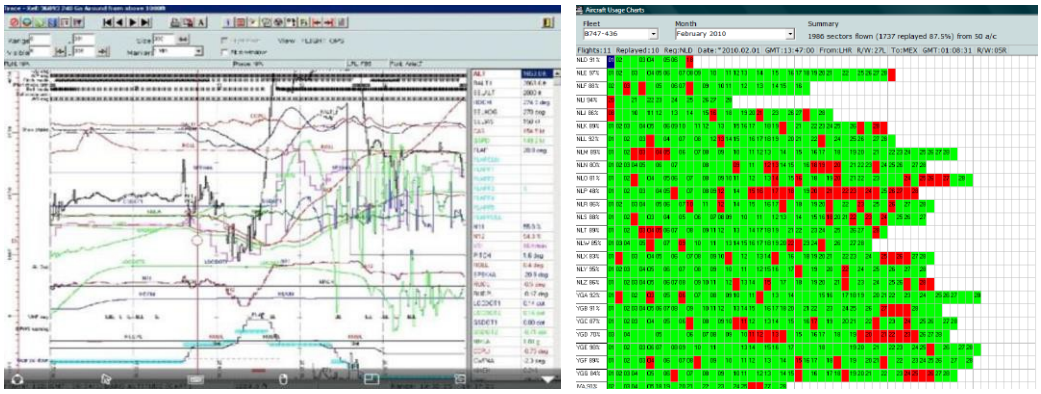


Figure A-14. FDP FDM360 – Flight parameters analysis and aircraft usage chart

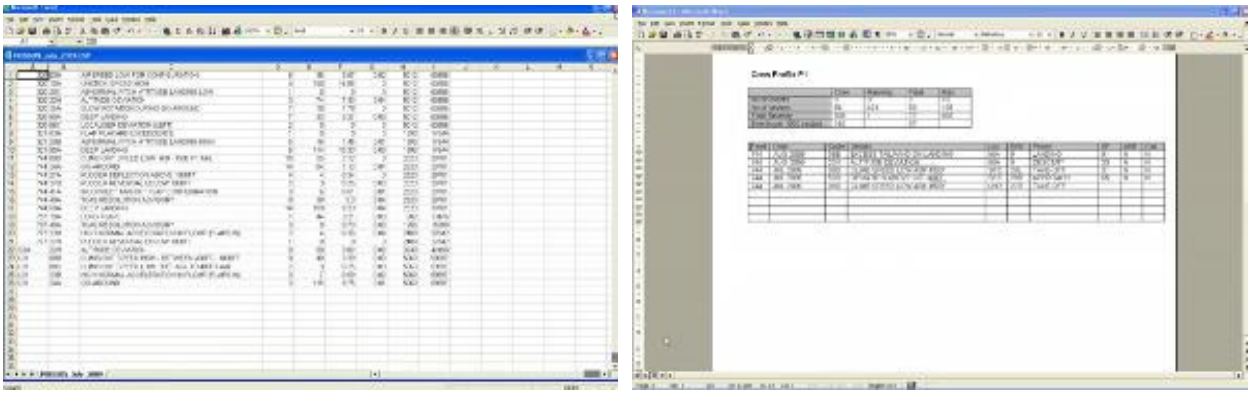


Figure A-15. FDP FDM360 – Data export and report generation

Figure A-16. RTI 720° Smart Animation™ and FDP FDM360 – 3D animations

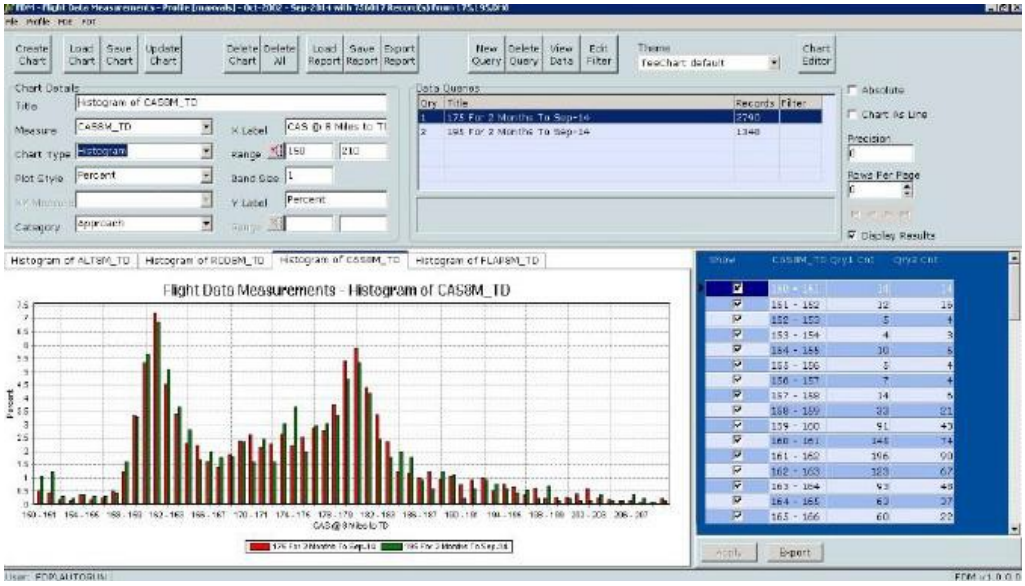


Figure A-17. FDP FDM360 measurements – Statistical analysis

The FDP FDM360 solution is also said to include "additional features such as data capture and extraction for fuel efficiency, EHM (engine health monitoring), APM (aircraft performance monitoring), aircraft usage and data capture statistics, admin/user control and audit tools and an optional crew performance profiling module" [42].

FDP FDM360 also offers safety management services that can be integrated with the FDP FDM360 software, such as:

- Gap analysis
- Safety planning
- Safety investigation
- Safety management assessment
- Safety cases
- Hazard and risk analysis
- Design and support of reporting systems
- Cost-benefit analysis

Flight Data Services: Flight Data Connect

Flight Data Connect is a web-based FDA software developed by Flight Data Services [43] that provides a range of FDM products and services, including [44]:

- Key Point Value analysis (gives a map of normal operation of aircraft as baseline for further analysis)
- Safety event analysis with high-risk moments detection

- Customized FDM/FOQA events and limits
- SOPs monitoring
- Maintenance analysis and monitoring
- Fuel usage analysis (efficiency and emissions reporting)
- Statistics and trends reporting
- Graphs, charts, and flight displays
- Interactive analysis dashboards with visualization, tabulated data and graphs (interactive graphs, cockpit displays, Google Maps view of airports, flight paths, and event clusters)
- Airport and weather database to supplement flight data (takeoff and landing METAR weather reports)
- Blending flight data results with pilot reports and air traffic control (ATC) procedures
- Event and performance benchmarking
- Training improvement capability
- Integration with a SMS
- Full service or hosted service
- Secured access to data and analysis results

Major features include:

- Compatibility
    - Compatible with common media and flight data (AMS Afirs, Avionica miniQAR, Avionica RSU-II, L3 F1000, L3 FA2100, L3 ROSE, L3 miniQAR, FDS HHMPI, Flight Data Vision SSQAR, Honeywell Handheld Download Unit, Honeywell FDAMS, Penny+Giles OQAR, Penny+Giles PQAR, Safran DFDAU, Safran FDIMU, Teledyne QAR, Teledyne WGL, Thales EQAR)
    - Multi-platform (Ubuntu, Windows, Vista™, Windows)
    - Offline data download

- Data transmission
    - Secure transfer protocol
    - Compression algorithms
    - Error recovery

- Flight data processing
    - Duplicate upload prevention
    - Flight splitting into sectors prior to upload
    - Data conversion with advanced data recognition algorithms (
    - Industry standard open protocols (HTTPS, WebDAV, XML-RPC, SHA1, JSON, REST, BZIP2, Geo IP tracking)
    - Modern open source languages (web server: Python™, Django, PostgreSQL Apache; transfer client: Python, wxPython, FilterType; Flight Data Services Open Source flow programming framework)

- Software support

    - Centralized administration automatic diagnostics of connectivity issues
    - Support team
    - Automatic upgrades

Guardian® Mobility

Guardian Mobility "is a leading provider of end-to-end solutions for global tracking, voice and data communications, Flight Data Monitoring and analytics service to the aviation marketplace" [55]. Guardian Mobility offers the all-in-one G4 device designed for both current and future FDM and SMS needs. The G4 "provides global, real-time tracking and two-way messaging all in one device" [56]. For example, it has the following capabilities:

- Automated Flight Following (AFF) for safety and situational awareness – real-time fleet tracking and connection using satellite and cellular voice communication through the Iridium satellite network [65])
- Two-way text for convenient communications with dispatch or ground personnel
- Built-in sensors for monitoring flight parameters such as temperature, descent rate and velocity
- Engine Trend Monitoring (ETM) for supporting MOQA
- Data collection for logbooks, maintenance data, and flight tickets

The hardware portion of the G4 records a variety of parameters, such as GPS position, altitude, speed, and time; air data speeds, temperatures, and altitudes; flight altitudes, attitude rates, and accelerations; engine data; weight on wheels, stall, and various alerts.

Guardian Mobility G4 can be used in concert with the SilverEyeAviation tracking and management software [56] in order to:

- Monitor the status (including location, altitude, landed status, etc.) of various types of assets (in the air, on land, or at sea)
- Define points ot interest on various charts and maps
- Display standard maps and overlays (such as flight charts, TFR, METAR, and TAF) on any smartphone or tablet
- Send two-way text messages
- Generate a variety of customizable reports and export them to other analytic system
- Customize views, potentially using the smart wall or split-screen capability to track multiple aircraft simultaneously
- Customize alerts that can be shared with other users and/or sent to dispatch or graound personnel

Helinalysis®

Helinalysis specializes in helicopter FDM (HFDM) services and applications, including but not limited to the following [57]:

- FDM consultations
- Fully hosted or on-site managed HFDM services
- Data capture and software selection advice
- SOPs monitoring
- Early maintenance warnings
- Statistical trend reports
- Engineering exceedances monitoring
- High-severity events validation
- Animation of specific flights of interest
- Training improvement efforts

For instance, Helinalysis has been working with Appareo Systems Flight Analysis Software™ [7] and Aerobytes FDM software [3].

Safran Electronics & Defense Tool Suite: Cassiopée

Safran Electronics & Defense Cassiopée is a constellation of aviation services based on Safran Global Data Services system [100]. It provides business aviation and helicopter operators with tools for safety and risk management, flight operations quality assurance, predictive maintenance, and crew training. It is powered by Cassiopée Analysis Ground Station (AGS) software [106] which performs automatic analyses from flight data recorders. It features the Cassiopée $SFCO_2$™ tool [105] which is aimed at identifying and tracking fuel consumption, reducing CO_2 emissions, and enhancing fleet operational efficiency. It is also composed of a specially designed Cassiopée FDM tool [101] which provides a range of statistical analyses and trend reports to identify and investigate safety events. The Cassiopée flight data service provides a variety of tools for safety management, risk assessment, quality assurance, 3D flight replay and animation, graphical analysis, trends and statistical reporting, maintenance troubleshooting, fuel consumption monitoring, and flight-operations efficiency. In particular, Cassiopée offers a FDM solution specific to helicopters, Cassiopée HFDM [102], which can be coupled with Cassiopée Helisafe [103] which includes flight safety, operations, and maintenance activity analyses as well as Cassiopée Digital Flight Report [104] for helicopters equipped with the Helicom V2+ flight data acquisition box.

Some of the main benefits of Cassiopée FDM include:

- Data analysis and visualization
- Customized events detection
- Graphical analyses
- 3D animations with flight profile and trajectory in Google Earth

- Statistical reports
- Safety risk assessment
- Corrective actions implementation and follow-up
- Operations efficiency improvement
- Experience sharing

Figure A-23 shows two general user interfaces of the Safran Electronics & Defense Cassiopée FDM software and a customized representation of some event-analysis results.

Figure A-23. Safran Electronics & Defense Cassiopée FDM

Cassiopée FDM most probably benefitted from the solution developed by Alyzair, the French pioneer in FDM, that was purchased by Sagem, now Safran Electronics & Defense, in 2010. However, the authors do not know how much of the initial capabilities have been retained within Cassiopée FDM. On its decomisioned website (accessible through the Wayback Machine[2]), Alyzair was claiming that it provided a wide range of FDM and MOQA services compliant with international regulations and standards. Some key features were as follows:

- 3D flight animation
    - Flight data replay
    - Flight parameters display
    - Customized instruments modeling
- Quality assurance tools

[2] Alyzair website: https://web.archive.org/web/20140310061857/http://www.alyzair.fr/fdm-services.html

  - Engine health and fuel monitoring
  - Aircraft performance monitoring
  - Airframe monitoring
  - Preventive and corrective actions implementation
  - Flight operations efficiency monitoring

- Safety management tools

  - Flight data analysis and reporting
  - Advanced and graphical analysis
  - Statistics and trend indicators
  - Operational risk assessment tool based on Airline Risk Management Solutions working group methodology

- Web-based interface

  - Online data management
  - Event validation
  - Interactive data analysis
  - Report generation
  - No software to install

Cassiopée AGS is a "semi-automatic analysis system of aircraft flight data, enabling operators to optimize maintenance management of their fleet and reduce costs (MOQA - Maintenance Operation Quality Assurance), while participating in Flight Operation Quality Assurance (FOQA)" [106]. AGS allows operators to perform automatic, statistical, or manual data processing, reporting, statistical analysis, investigation, and decision-making. For instance, users can:

- Investigate events in detail
- Identify hazardous conditions
- Select various types of analysis displays (charts, curves, graphs, and other visual representations)
- Study the effects of weather on safety
- Produce predefined or customized reports
- Edit, publish, and export reports in various formats
- Monitor airplane and engine conditions (fuel consumption, brakes, tires, and landing gear wear, taxi time, etc.) for preventive maintenance and operational efficiency purposes
- Use analysis results for training purposes
- Share experiences
- Produce realistic 3D animations using the integrated CEFA Flight Animation Software [21], and synchronize them with curves and tabular data
- Perform safety management and risk assessment using Q-Pulse® [66]

Figure A-24 shows various types of analysis that can be performed using Cassiopée AGS, such as events and parameters time series, six sigma chart for flight safety analysis, flight replay in a

realistic 3D environment, and integrated 3D bundle (such as 3D animations, instrument displays, approach plates, curves, and tabular data).

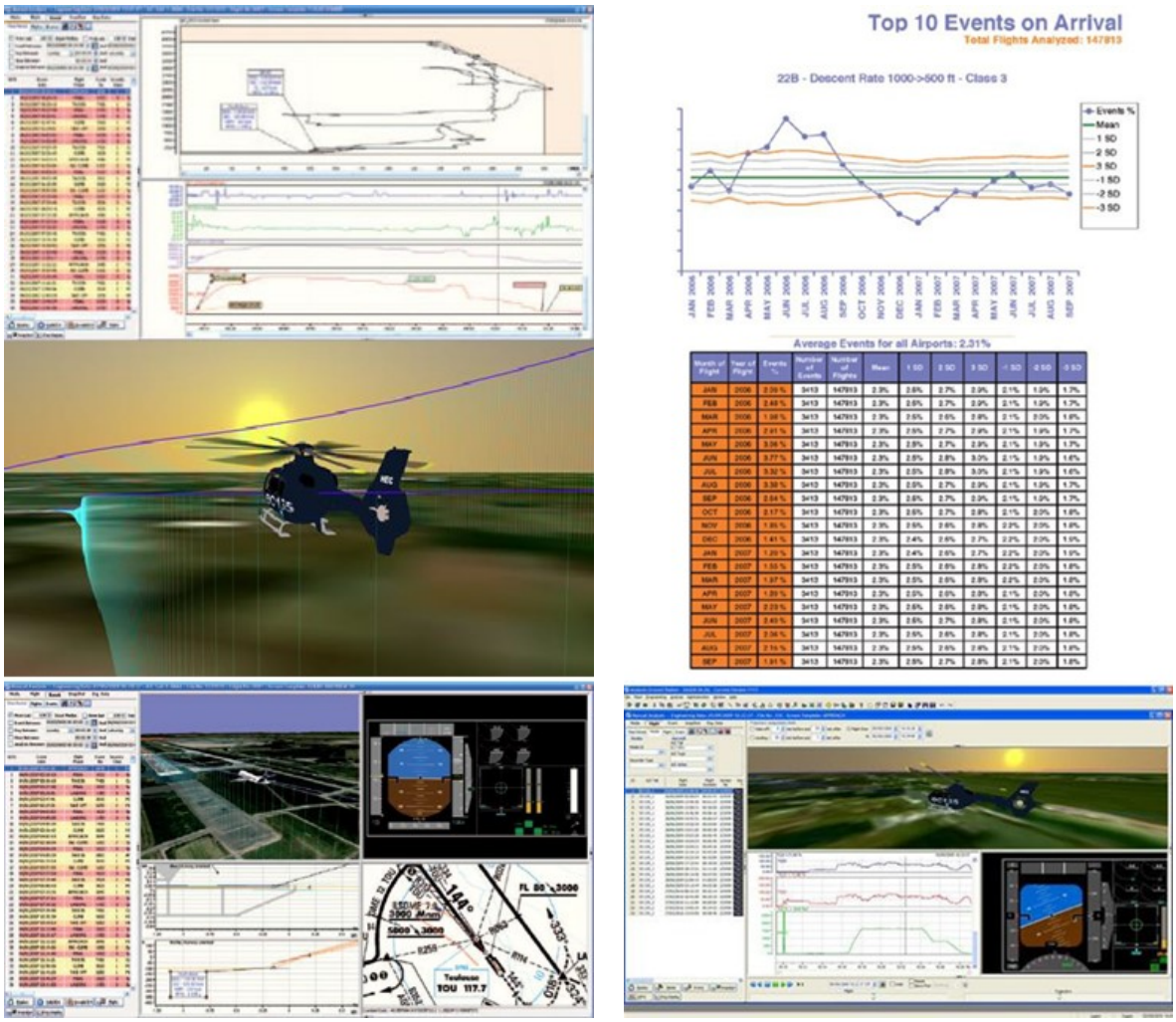


Figure A-24. Cassiopée AGS software

SimAuthor Tool Suite: FlightAnalyst®, FlightViz®

SimAuthor developed the FlightAnalyst and FlightViz software applications to improve maintenance, operations, safety, and training [108]. FlightAnalyst provides a means to transform raw data into informative charts, graphs, curves, reports, and briefing or debriefing sheets. It can be linked to FlightViz to visualize the data in sequence and show details of a specific event of interest. FlightViz provides a means to interactively visualize and analyze flight data in a high-fidelity 3D environment. It displays the flight from both inside and outside the cockpit, overlays navigational charts over the terrain, and shows real-time cockpit instruments. When combined, FlightAnalyst and FlightViz enable operators to enhance crew training, increase engine and airframe efficiency, optimize preventive maintenance, improve safety of flight operations, analyze

complex aircraft data in a synchronized environment with 2D and 3D information, and detect dangerous trends so that corrective actions can be implemented.

Maintenance

Using flight data records for various aircraft components and running automatic analyses to detect exceedances, FlightAnalyst allows maintenance personnel to rapidly identify the causes of an event, have a system view of actual failures, analyze long-term fleet trending, perform preventive maintenance on the most solicited aircraft or engine components, and document maintenance issues. As for FlightViz, it provides a global picture of both internal and external factors potentially leading to a system failure, such as cockpit instruments, environmental conditions, and pilot actions. Figure A-25 shows how FlightAnalyst and FlightViz can be used to optimize preventive maintenance.

Figure A-25. SimAuthor FlightAnalyst and FlightViz for maintenance optimization

Operations

FlightAnalyst and FlightViz can also be used to enhance the efficiency and effectiveness of flight operations. For instance, FlightAnalyst provides the capability to study various operational trends (such as fuel consumption and wear-and-tear of engine and aircraft components) using either particular flight data or aggregated flight data. FlightViz enables operators to visualize various types of airport features in a 3D environment using the FlightViz's AirportFAM module, and 2D graphs, curves, and charts. FlightViz also supports mission planning and crew briefing and debriefing. Figure A-26 shows how FlightAnalyst and FlightViz can be used to enhance the effectiveness and efficiency of flight operations.

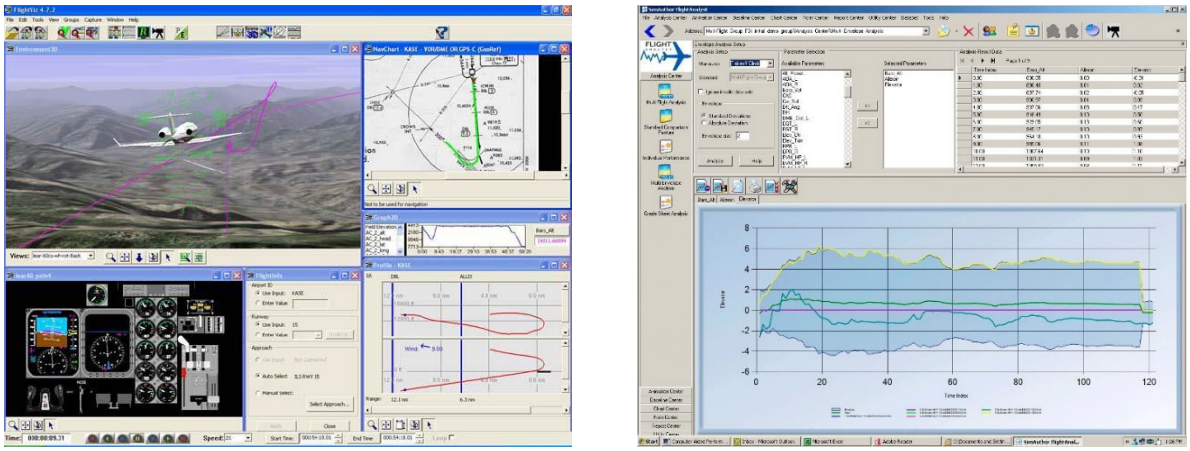


Figure A-26. SimAuthor FlightAnalyst and FlightViz for optimization of flight operations

Safety and training

FlightAnalyst and FlightViz can further help operators investigate the safety of their flight operations to prevent incidents, accidents, and events before they occur, and to enhance crew training. For instance, FlightAnalyst can be used to review and analyze flight data, detect dangerous trends, and quickly disseminate the results to the community, whereas FlightViz can be used to concurrently visualize the various parameters that led to an event by combining 3D flight replay and 2D graphs, curves, and charts. Figure A-27 shows how FlightAnalyst and FlightViz can be used to enhance the safety of flight operations by investigating and visualizing events and by efficiently disseminating analysis results.

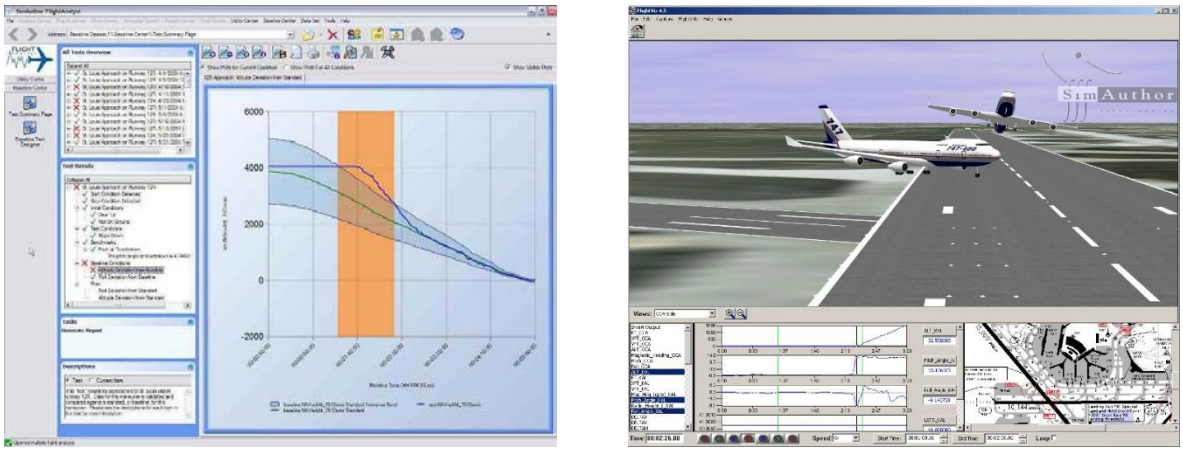


Figure A-27. SimAuthor FlightAnalyst and FlightViz for safety enhancement

Swiss 49

Swiss 49 offers three different types of FDM services, namely FDM, flight operations efficiency, and flight data research [114]. Swiss 49 Flight Data Monitoring service is based on selected FDM

computer systems and on the Airbus-NAVBLUE AirFASE flight animation software [5]. It provides operators with the ability to:

- Customize their flight data analysis
- Analyze the safety of their flight operations
- Optimize flight operations efficiency
- Assess risks by identifying event occurrences
- Compare safety risks with other operators
- Determine corrective actions
- Identify and proactively respond to event triggers and exceedances
- Generate printable reports
- Optimize maintenance troubleshooting
- Manage compliance to operational efficiency policies
- Monitor training activities
- Monitor fuel consumption
- Generate fuel efficiency reports
- Monitor overall performance
- Visualize flight data in a high-quality 3D environment
- Manipulate flight data to make more informed decisions
- Perform data mining
- Optimize data and processing specification

Swiss 49 can also help operators develop and run an effective SMS composed of the following elements:

- Safety objectives
- Safety performance indicators
- Safety culture, policies, and processes
- Safety audits
- Safety reviews
- Safety training
- Hazard identification
- Risk assessment, management, and control
- Dissemination of safety-related information
- Planning of safety strategies and resources
- Evaluation of safety tools
- Safety risk management database
- Flight Data Monitoring System

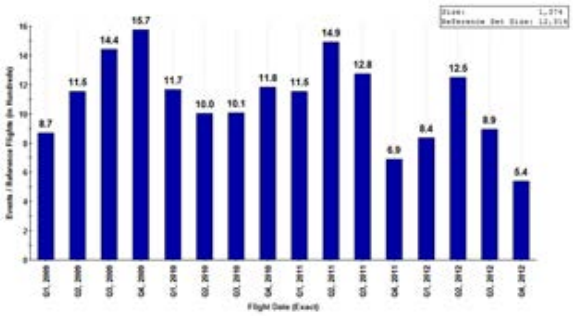
Figure A-28 shows various components of the HFDM services offered by Swiss 49: (a) event definition; (b) statistical analysis; (c),(d),(e),(f),(g),(h) various types of graphs for event investigations; (i) data mining; (j) 3D flight animation; (k) trajectory analysis; (l) SOPs analysis; (m) events analysis during approach and landing; and (p),(q) various types of graphs for fuel consumption monitoring).

Unstable Approach Events	Phase of Flight	Measurement Criteria		C-FOQA SEL		units
Runway Alignment				Caution	Warning	-
1) Above Desired Glide Path	500 ft HAT - 200 ft AGL	One Standard Deviation above Average Glideslope	>	2	-	dots
2) Below Desired Glide Path	500 ft HAT - 200 ft AGL	One Standard Deviation below Average Glideslope	<	-1.3	-3	dots
3) Not Aligned with Runway (Localizer)	500 ft HAT - TD	One Standard Deviation outside Average Localizer	>	1	-	dots
Airspeed						
4) Fast Approach (Airspeed vs. Vapp)	500 ft HAT - 50 ft AGL	One Standard Deviation above Avg (Airspeed - Vapp)	>	20	25	knots
7) Slow Approach (Airspeed vs. Vapp)	500 ft HAT - 50 ft AGL	One Standard Deviation below Avg (Airspeed - Vapp)	<	-10	-	knots
Rate of Descent (ROD)						
9) High Rate of Descent	500 ft HAT - TD	ROD ÷ ROD Limit*	>	0	10	%
Configuration						
11) Final Flap Change is Late	Descent & Approach	HAT at Last Flap Change	<	-	500	feet
12) Final Flaps Not Valid for Landing	Descent & Approach	Final Flap Setting	<	Landing Flaps	-	degrees
13) Gear Extension is Late	Descent & Approach	HAT at Gear Extension	<	1000	500	feet
Aircraft Body Rates						
14) Unsteady in Pitch	500 ft HAT - 100 ft AGL	Standard Deviation of Pitch Rate	>	1.5	-	deg/sec
15) Unsteady in Roll	500 ft HAT - 50 ft AGL	Standard Deviation of Roll Rate	>	4	-	deg/sec
16) Unsteady in Yaw	500 ft HAT - 100 ft AGL	Standard Deviation of Yaw Rate	>	3	-	deg/sec

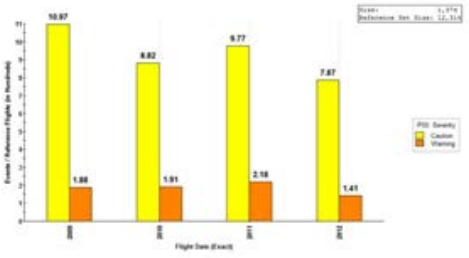
*Rate of Descent Limit Changes with Altitude and Glide Path Angle and has a Lower Limit of 1200 ft/min

(a)

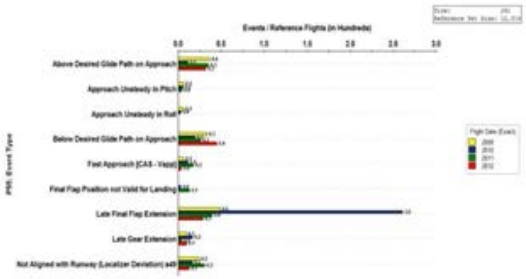
(b)



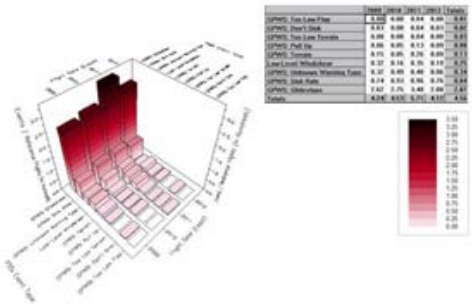
(c)



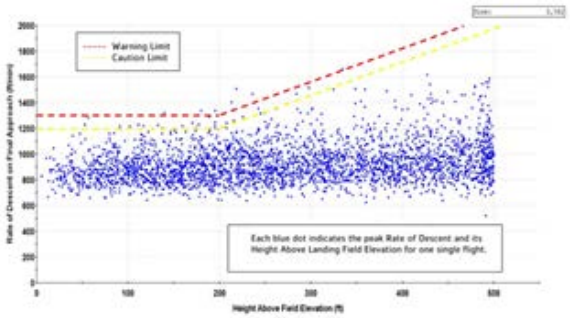
(d)



(e)



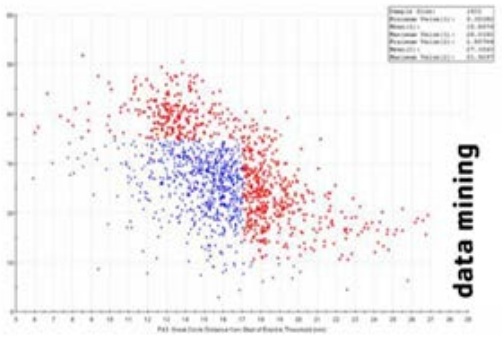
(f)



(g)

Figure A-28. Swiss 49 HFDM

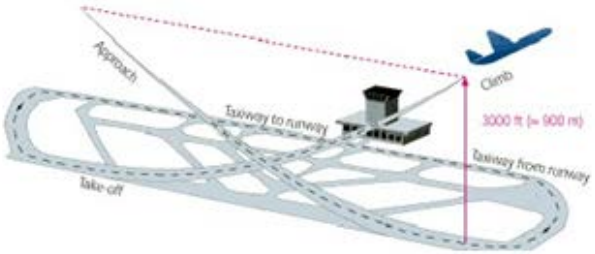
(h)



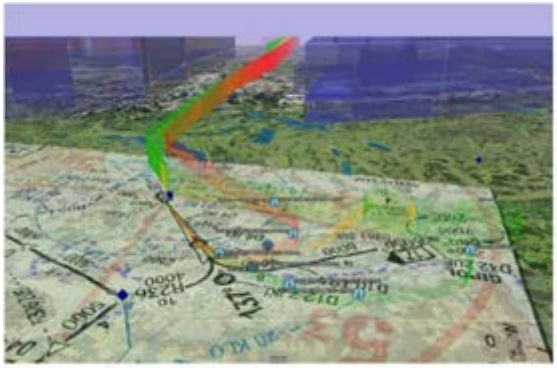
(i)

(j)

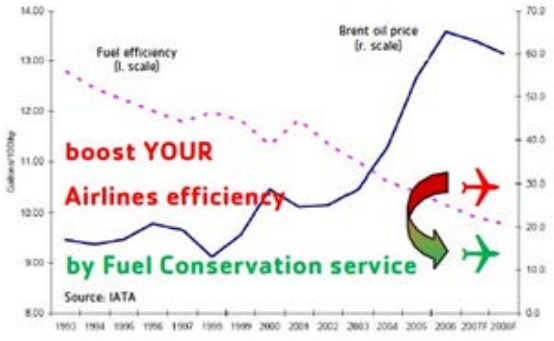
(k)



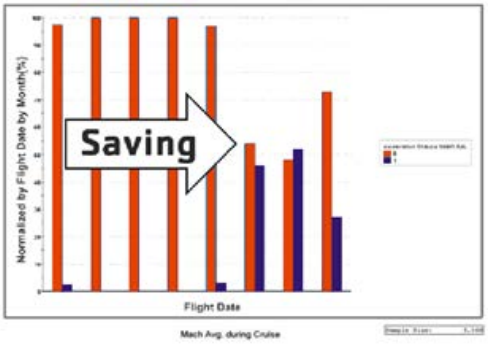
(l)



(m)



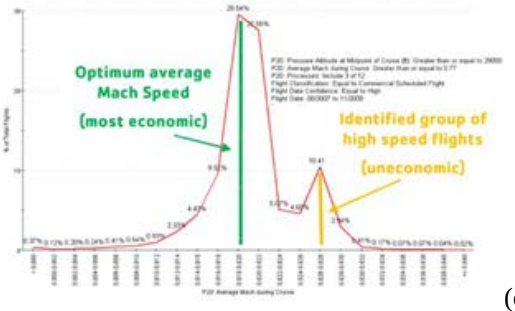
(n)



(o)

Figure A-28. Swiss 49 HFDM (continued)

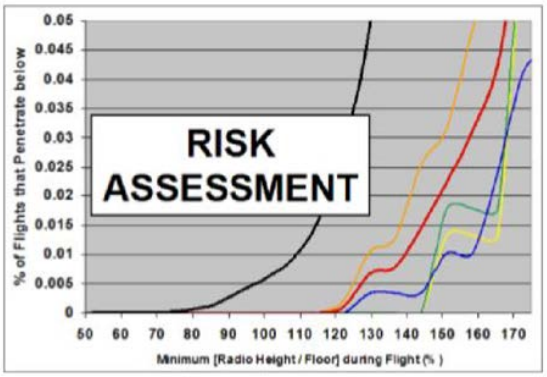
(p)



(q)

Figure A-28. Swiss 49 HFDM (continued)

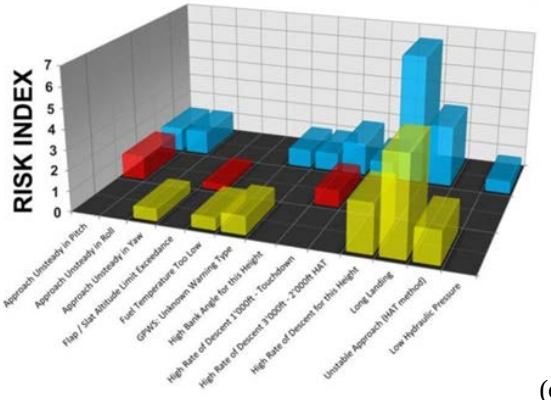
Figure A-29 shows how risk assessment is performed in the Swiss 49 FDM Risk Assessment Module: (a) generic risk assessment graph; (b) risk matrix with risk severity and probability; (c) risk index or product between risk severity and risk probability; and (d) risk tolerability matrix.



(a)

Severity						
	Catastrophic 5	5	10	15	20	25
	Critical/Hazardous 4	4	8	12	16	20
	Serious/Major 3	3	6	9	12	15
	Marginal/Minor 2	2	4	6	8	10
	Negligible 1	1	2	3	4	5
		Probability of Occurence				
		Improbable 1	Remote 2	Occasional 3	Probable 4	Frequent 5

(b)



(c)

ASSESSMENT RISK INDEX	RISK MANAGEMENT CRITERIA
Risk Value 15 to 25	**Unacceptable** (Cease Operation and Mitigate/Control Risk)
Risk Value 9 to12	**Undesirable** (Mitigate and Control Risk)
Risk Value 6 to 8	**Tolerable** (Review and Monitor Risk)
Risk Value 1 to 5	**Acceptable**

(d)

Figure A-29. Swiss 49 HFDM risk assessment

Wi-Flight

"Wi-Flight is a FDM/FOQA cloud-based product/service developed by General Aviation Safety Network (GASN) [51], a subsidiary of Aero Teknic Inc. [4]" of Quebec in Canada [121]. Wi-Flight is a subscription-based service that features Internet-based flight replay and automatic flight data analysis.

The flight replay package includes the following capabilities:

- 3D flight replay using Google Earth plug-in
- Cockpit view and rear view
- 3D flight export in KML format
- 2D moving map with track view and pan/zoom options using Google Maps
- Flight track print option
- Playback options (play, pause)
- Volume controls for radio/intercom and ambient noise
- GPS data replay (groundspeed, altitude, vertical speed, vertical G's)
- Terrain elevation data from NED, SRTM or ASTER
- Weather data, such as winds from METAR at time and location of flight path

The flight analysis package includes the following capabilities:

- Event detection and analysis
- SOPs monitoring
- Flight, ATC, and weather data fusion
- Training optimization
- Experience sharing

Figure A-30 shows some examples of visualization interfaces obtained with the Wi-Flight HFDM software flight analysis and flight replay modules.

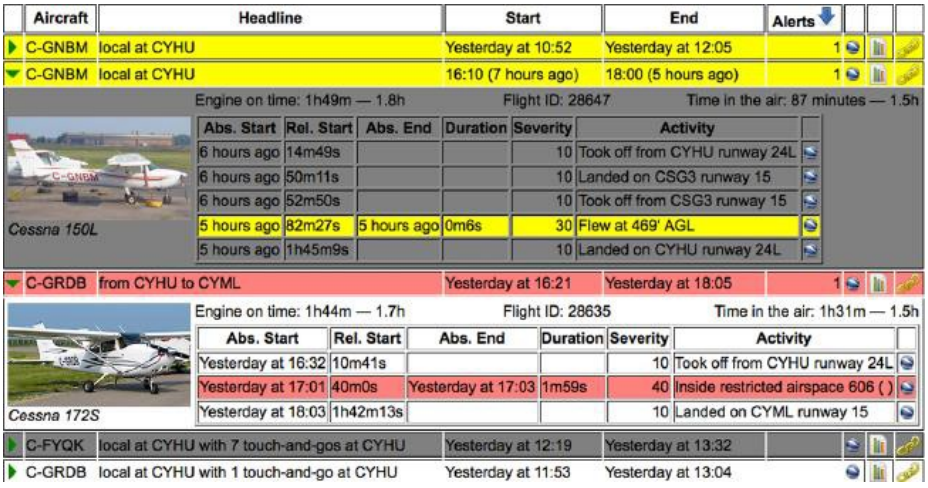


Figure A-30. Wi-Flight flight analysis and flight playback

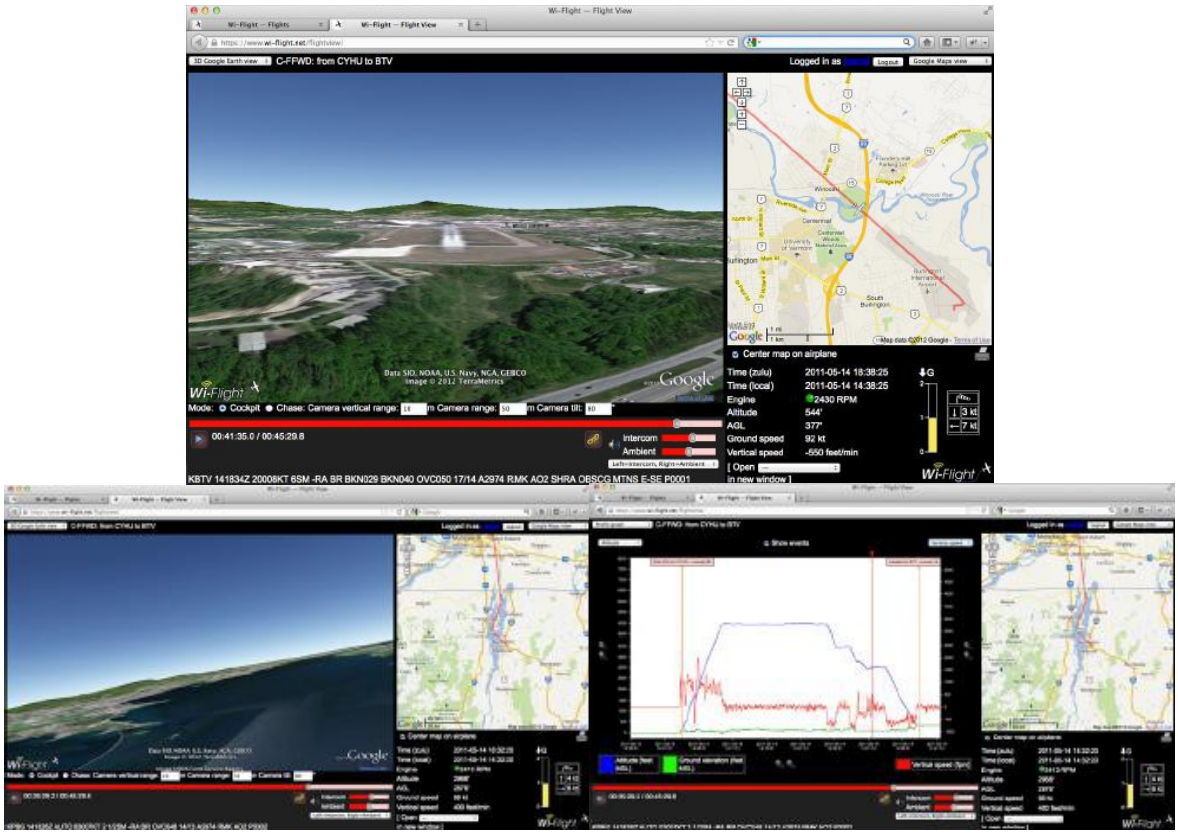


Figure A-30. Wi-Flight flight analysis and flight playback

APPENDIX B—RISK MANAGEMENT TOOLS DESCRIPTIONS

Refinitiv® Risk Manager

Refinitiv Risk Manager enables organizations to capture and manage information regarding their operational risk levels. It provides a suite of built-in tools to understand risks, prevent and know how to respond to identified risks, and detect and respond to emerging and unknown risks. The basic risk management framework is composed of four main elements:

1. Risk identification – Identify all significant risks (both existing and emerging) and their potential outcomes.
2. Risk analysis and evaluation – Identify potential causes of risk events, forecast their consequences, and understand their probability and impacts.
3. Risk treatment – Prevent risks from occurring and reduce the magnitude of their consequences if and when they occur, and establish techniques for early risk detection.
4. Risk register – Create a register of all significant risks across the organization in which risks are rated and prioritized.

The first step in this framework enables company executives to assign risks and delegate their treatment to relevant people in the organization and to ensure that risks are efficiently monitored and treated. The second and third steps of the framework allow stakeholders, executives, and employees to concurrently and simultaneously review the level and status of each risk level and the status of mitigating actions. They also provide a means to add new risks and remove risks that have been driven down to the acceptance level of the company. Finally, the fourth step in this framework ensures that risk intelligence is built progressively and that relevant risk data and information are efficiently and effectively communicated and regularly reported to all stakeholders, executives, and concerned employees.

More specifically, Refinitiv Risk Manager is composed of five connected modules that enable holistic risk solving and communication of relevant findings:

- Incident tracking to capture loss events, incidents, and near misses across the organization to better understand how often certain types of risks are encountered and what impacts they have on the company's strategic goals.
- Assessments to design a custom assessment program supporting the company's risk appetite and culture. Assessments can be anything from checklists to sophisticated risk control self-assessment with scoring and calculations.
- Indicators to define and display various types of key indicators, such as risk indicators and control indicators that help drive business decisions.
- Quantification to analyze existing operational or enterprise risk exposures and to understand potential future risk impacts through a range of tools, including aggregated risk simulation, multi-level aggregations, independent risk simulations, and scenario modeling from various data sources, including loss data, scenario data, and conditioning via key risk indicator data.

- Action management to create and assign action plans and individual tasks to various people in the company.

Figure B-1 shows an overview of the Refinitiv Risk Manager module interface.

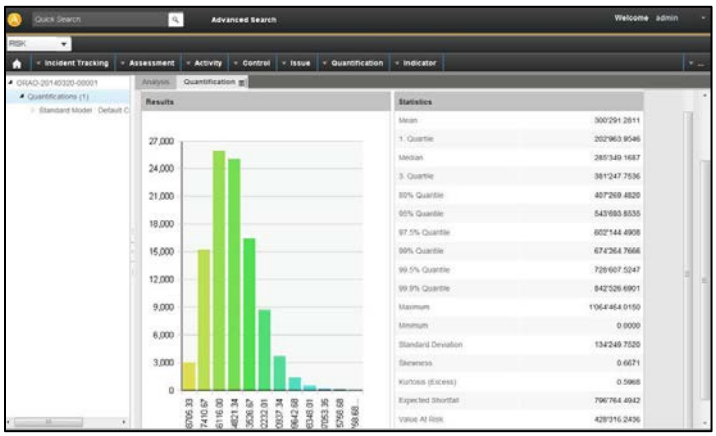


Figure B-1. Refinitiv Risk Manager

Refinitiv Risk Manager is part of a larger set of solutions designed to help management enhance the value of their governance, operational and enterprise risk, and compliance framework. Other relevant solutions are Refinitiv Audit Manager and Refinitiv Compliance Manager, including Refinitiv Regulatory Intelligence.

The Refinitiv Audit Manager module allows audit teams to plan and schedule audits and internal reviews, track the status of risk mitigation strategies, automate risk assessments, manage documentations related to audits and risk mitigation, implement action plans to resolve audit and risk mitigation issues, review and approve audits, and share information about the audit process and findings by designing, generating, and distributing customizable reports. Figure B-2 shows an example of dashboard and displays generated with the Refinitiv Audit Manager module.

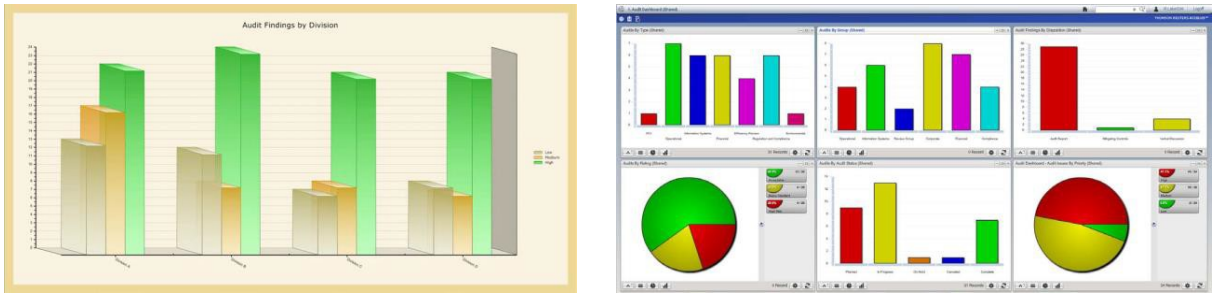


Figure B-2. Refinitiv Audit Manager

The Refinitiv Compliance Manager module allows management to establish clear relationships between regulations and internal business structures, policies, and risks; link regulatory events to relevant risks, policies, and risk mitigation techniques, and communicate this information to interested parties; manage and share regulatory information, risks, policies, and risk-mitigation

strategies across the organization; capture data workflow and support compliance activities; document and manage the impacts of regulatory events and the required actions that ensure compliance; centralize documentation related to issue management and remediation for compliance purposes; and increase compliance transparency through alerts, status reports, and dashboards. The Refinitiv Regulatory Intelligence module enables users to include the relevant regulators, governing bodies, and entities in their compliance process; obtain guidance on key regulatory themes; and receive timely updates and alerts on regulatory changes affecting the organization. Figure B-3 shows an example of dashboard and displays generated with the Refinitiv Compliance Manager and Regulatory Intelligence modules.

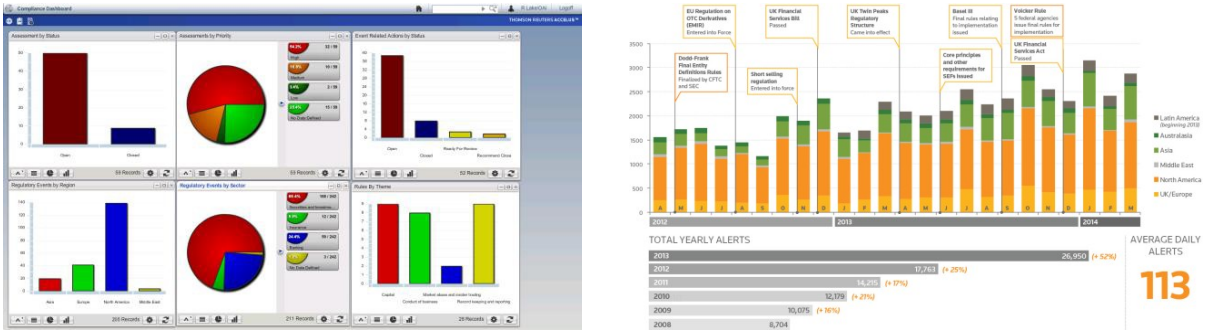


Figure B-3. Refinitiv Compliance Manager and Refinitiv Regulatory Intelligence

Mitratech Compliance Risk Management Software

Mitratech Compliance risk management software (RMS) is a component of the larger Mitratech Compliance SMS software, which is specifically designed to reduce operational and enterprise risk and improve performance [76]. Mitratech Compliance RMS is designed to provide organizations with "an integrated, scalable and flexible risk management framework for documenting and assessing risks, defining controls, managing audits, identifying issues and implementing recommendations and remediation plans" [77]. Mitratech risk management solution is composed of several modules for risk analysis and monitoring.

The risk register module ensures that operational risks are being appropriately handled at the enterprise level. It allows executives to view detailed information about identified risks, such as probability of occurrence, potential consequences, person in charge of mitigation, current corrective measures, and status of mitigating strategies, etc.

The risk assessment module ensures that both existing and potential risks and hazards are being identified, scored, classified, and mitigated at the enterprise level and that relevant information is being communicated across the organization. It further provides the ability to monitor current practices and policies and assess their compliance with applicable regulations.

The incident management module ensures that occurrences or incidents are being monitored appropriately. An occurrence or incident can be a risk that has been identified and evaluated or a lack of compliance to a policy, a procedure, licensing, or a standard. A potential impact of an occurrence or incident can spread across financial, environmental, and social domains. In this

context, the incident management module provides an integrated and automated framework for effective notification, causal investigation, and reporting of occurrences or incidents and their consequences across the organization.

The management of change module manages the complete process of identifying, evaluating, analyzing, and mitigating occurrences and incidents to ensure that any changes in operational or organizational structures minimize the associated risk.

The documents and policies module ensures that relevant documents and records are being efficiently and effectively controlled, distributed, and attested to by the right people in the organization.

The meeting management module ensures that an audit trail of all current and past meetings and related documents is being maintained, including attendees' assigned actions and their status of completion. It also allows automatic scheduling of meetings between interested parties when actions are required and proper recording and tracking of attendance to meetings.

Figure B-4 shows a notional dashboard example for the Mitratech Compliance RMS.

Figure B-4. Mitratech Compliance RMS

EtQ RMS

EtQ's RMS belongs to a larger family of modules intended to provide a fully integrated aviation SMS [32],[33],[34]. It is composed of four main categories of tools: risk analysis, risk recording and reporting, and risk prediction.

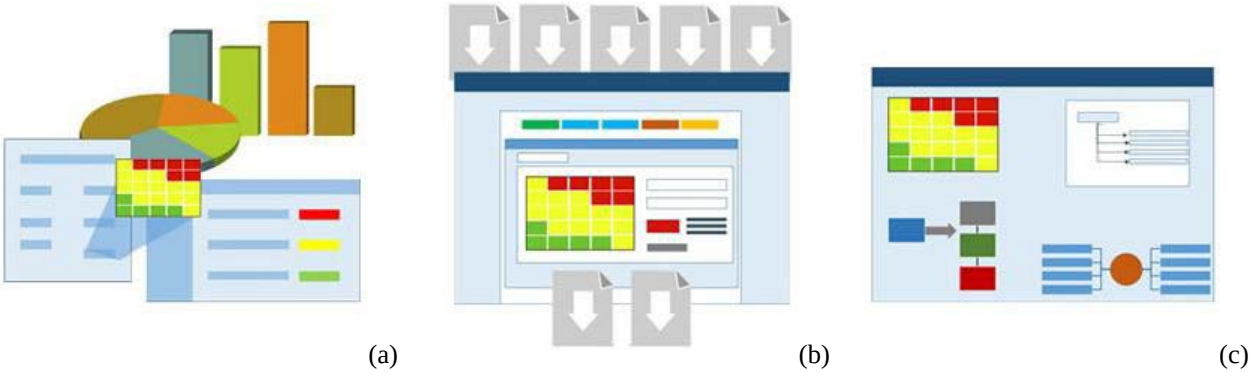
EtQ's quantitative risk analysis tools are designed to leverage multiple risk models, such as risk matrices; failure mode and effects analysis (FMEA); decision trees; hazard analysis and critical control point; or Bowtie models to automatically, systematically, and objectively calculate risk and to filter and categorize events by risk levels.

EtQ's risk register is a suite of recording and reporting tools built to provide a holistic risk picture within the organization. It is composed of three major components: 1) the risk history module, which creates a history of current and past risk within the register; 2) the risk reporting module, which identifies trends and performs risk analysis across various operational areas within the organization; and 3) the Enterprise Risk Management (ERM) module, which generates reports on risks and on the ERM performance. The goal of EtQ's risk register is to help companies filter out noncritical events and investigate only those events that have a critical impact on the enterprise with respect to compliance.

EtQ's Bowtie Risk Management tool is designed to help mitigate risk at the enterprise level by allowing concerned parties to put in place any number of controls to a single-risk event, identify and map out risks across different operational areas, measure the effectiveness and efficiency of mitigating strategies, and analyze the impacts of corrective actions on the associated risks.

EtQ's RMS can be combined with EtQ's Corrective Action and Preventive Action (CAPA) software to track risk mitigation strategies and ensure corrective and preventive actions actually reduce risks to appropriate levels. EtQ's CAPA software automates the process of assigning tasks and activities to relevant individuals or groups of individuals, tracking and recording progress and deliverables associated with each assignment, creating additional action items as needed, notifying assigned users of pending actions, notifying project leaders when a review and approval of an action item is required, and recording and reporting the complete action-plan history, related documents, and activities for future reference. EtQ's RMS works concurrently with EtQ's ERM software to define risk in various operational areas and come up with a unified method of solving high-risk events across the enterprise. EtQ's ERM software can be used to involve various individuals across the enterprise to assess risk, establish a plan for specific risk templates, establish a control plan, and monitor the efficiency and adequacy of the established corrective and preventive actions at the enterprise level. Finally, EtQ's RMS uses EtQ's centralized reporting and analytics capability to help make sense of risk data to make better decisions. EtQ's centralized reporting module allows users to create charts and configurable dashboard views in which the information can be logically depicted, searched for, and filtered, and custom report templates and formats to distribute trend and statistical analysis results to the relevant people.

Figure B-5 gives a notional example of how EtQ's RMS handles risk: (a) risk assessment; (b) adverse effects filtering; and (c) risk models.



(a) (b) (c)

Figure B-5. EtQ RMS

Ideagen

Ideagen provides safety, quality, risk and performance management solutions through the Q-Pulse software so that operational activities can be proactively approached [66].

Ideagen Helicopter Solution enables organizations to proactively manage risk in real time by integrating all available intelligence within the organization [67]. Ideagen Helicopter Solution uses visualizations from CGE Risk Management Solutions BowTieXP® software [23] to promote widespread understanding of risk across the organization, effective management of all risks and corrective actions in place, global understanding of the impact and extent of changes to mitigating strategies, and the sharing of lessons learned and best practices across the entire organization. BowTieXP is a risk assessment tool that helps visualize complex risks using the Bowtie method.

A Bowtie diagram is shaped like a bowtie, which creates a clear distinction between reactive and proactive risk management. A Bowtie diagram starts with the definition of a hazard that has the potential to cause damage if control over that aspect is lost. It then defines the event that could occur if control over that hazard is lost. For instance, a hazard can be the presence of an explosive material in a facility and the associated event can be that the explosive material is ignited. Threats are then defined as potential causes to the event. For instance, the explosive material can be ignited by a person, during a thunderstorm, a leak, due to a non-conforming container, a damaged or corroded container, an increase in the storage room temperature, or by being exposed to the sun through a glass window. Consequences are defined as the potential outcomes of the event. For instance, the explosion of the ignited explosive material may result in human injury or fatality, facility destruction, environmental pollution, reputation damage, or financial loss. Every line connecting a potential threat to a potential consequence through the event now represents a different potential incident scenario that needs to be controlled. Although some incident scenarios may have already occurred, most of the incident scenarios identified through a Bowtie diagram have actually not occurred yet. This makes the Bowtie method a proactive approach to risk. Once a Bowtie is created for a specific hazard, one can define barriers to interrupt the flow of potential incident scenarios so that threats do not result in a loss of control or escalate into actual impacts. In the example above, a barrier can be a periodic examination of the structural integrity of the explosive material container to check for conformity, any obvious leak, or corrosion. Once barriers

are identified, they can be assigned to specific individuals for implementation and monitored to determine how critical they are to the organization, how they perform, and what activities need to be implemented for those barriers to be maintained. Finally, factors that may compromise the success of a barrier can be defined. These factors are called escalation factors. For instance, explosive materials stored in a room with a door that opens and closes using an electrical mechanism can be at risk if there is a power failure. To conclude, a Bowtie diagram can be used to visualize potential threats, their associated consequences, the types of barriers put in place to control risk, the effectiveness of those barriers, and the persons responsible for the implementation of activities necessary to maintain those barriers. In a risk environment, Bowtie diagrams are used to identify risks and their associated threats and consequences, define and monitor potential corrective and preventive actions, and efficiently and effectively communicate about risk across an organization. Figure B-6 shows an example Bowtie diagram.

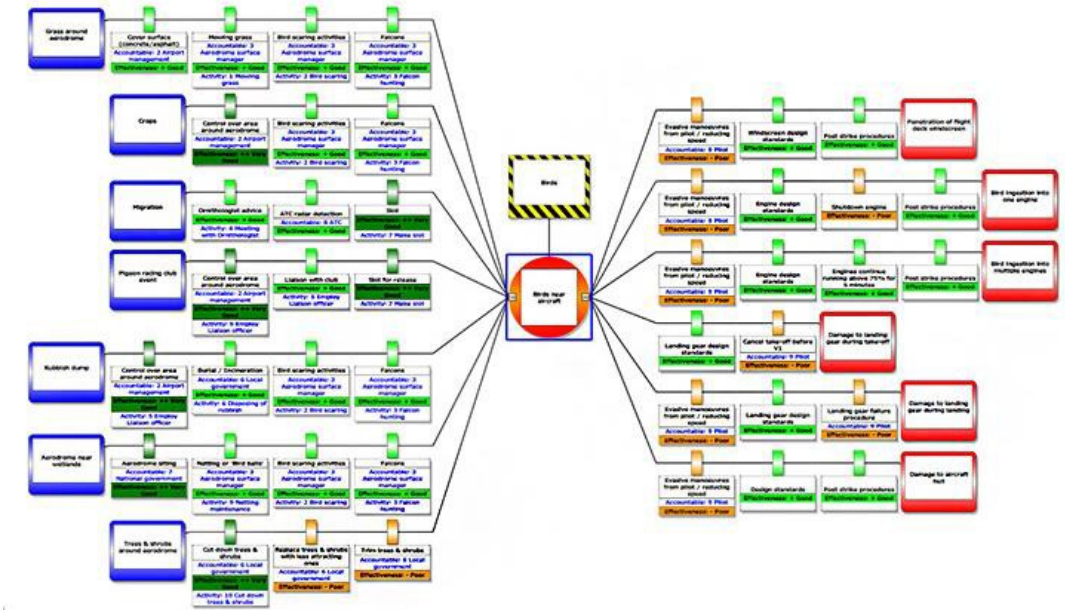


Figure B-6. Example Bowtie diagram

With the help of BowTieXP, the Ideagen Helicopter Solution software is designed to help organizations identify, understand, quantify, prioritize, mitigate, assess, manage, monitor, and review risk across the organization to build an effective and efficient risk management process. Ideagen Helicopter Solution is composed of three major layers: 1) a risk communication and consultation layer, 2) a risk analysis layer, and 3) a risk monitoring and review layer.

The risk communication and consultation layer allows management to create risk registers in which risks can be mapped to specific areas of operations, manage access to the risk register by specific individuals and their permissions to perform various tasks, send email notifications to stakeholders and accountable persons about risk events of interest, generate full reports and risk alerts, and allow people to create their own view of risks to perform assigned actions.

The risk analysis layer starts with the definition of elements establishing the context in which risk will be analyzed. For instance, it allows management to define the hierarchical structure of the

organization, create several risk matrices summarizing organization-specific risk evaluation criteria and risk appetite, assign roles to individuals across the organization to reflect their risk management responsibilities, and specify appropriate compliance requirements. Then, the risk analysis layer proceeds with the assessment of risk, which includes:

- Risk identification, in which risks are identified and assigned to competent individuals or groups of individuals for mitigation.
- Risk analysis, in which identified risks are linked to potential causes, associated threats, corrective and preventive control measures, recovery control measures, potential consequences, and to supporting documents and images. Risks are visualized using bowtie displays, which help determine the effectiveness of preventive and recovery actions.
- Risk evaluation, in which multi-perspective risk matrices are used to evaluate both inherent and current risk, and risk evaluations and residual risk levels are being recorded.

The risk analysis layer proceeds with the treatment of risk in which a decision is made whether to accept or treat the risk. When treatment is required, a target risk rating is defined, specific preventive and corrective actions are assigned based on the risk appetite of the organization, and a review and treatment plan is established to monitor control actions status through completion. The risk analysis layer concludes with risk acceptance, in which acceptance decisions by management are recorded based on the achieved risk level after treatment.

The risk monitoring and review layer allows management to monitor the effectiveness of preventive and corrective actions; get a holistic view of risk management and make timely decisions; generate customizable risk reports; visualize historic records of key events and associated risks; and maintain an audit trail of risk management activities.

Figures B-7, B-8, and B-9 show notional representations for each layer of Ideagen Helicopter Solution.

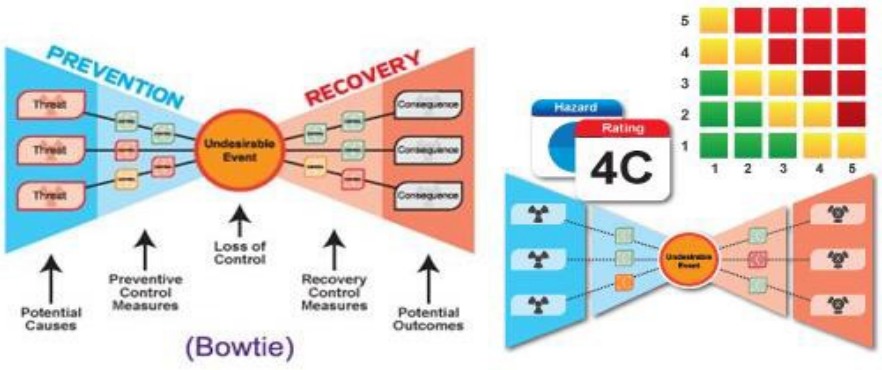


Figure B-7. Risk understanding and assessment

Figure B-8. Risk treatment or acceptance and risk visibility

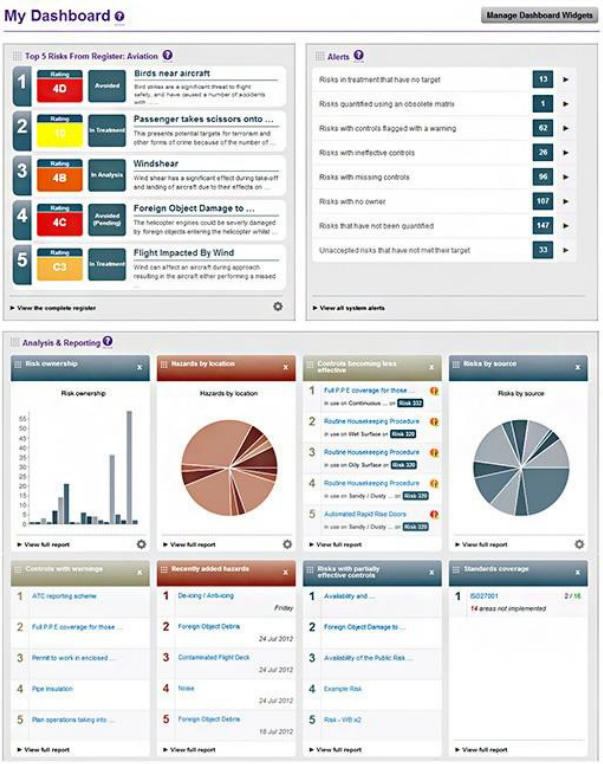


Figure B-9. Risk reporting and communication

IndustrySafe

IndustrySafe is a safety management software with a risk component designed to deal with hazards, incidents, and corrective actions through three specifically developed modules [58].

The hazards module is designed to identify, analyze, track, and eventually remediate hazardous conditions using a set of tools for hazard analysis, monitoring, tracking, and reporting. Hazards can be the result of incidents, inspections, design reviews or modifications, operations, or internal and external audits. Corrective actions can be defined for hazards of interest, and multiple hazards can be linked to a specific event to facilitate investigation and tracking. Hazards can be analyzed

by using a hazard matrix, which records its severity and probability of occurrence to assess the risk associated with this hazard. Several other analytics tools allow safety managers to find the root cause of a hazard; view a hazard by source, department, and operational area; and visualize the general hazard space across the organization. Email notifications and escalation emails can be sent automatically to notify supervisors when a hazard is created or closed, or if corrective actions are not completed by their estimated due dates. Finally, the hazard module allows safety managers to generate a variety of reports on hazard analysis, upload supporting documents, export data to other applications, and monitor hazard metrics across the organization.

Figure B-10 shows examples of a risk assessment matrix and a hazard reporting form.

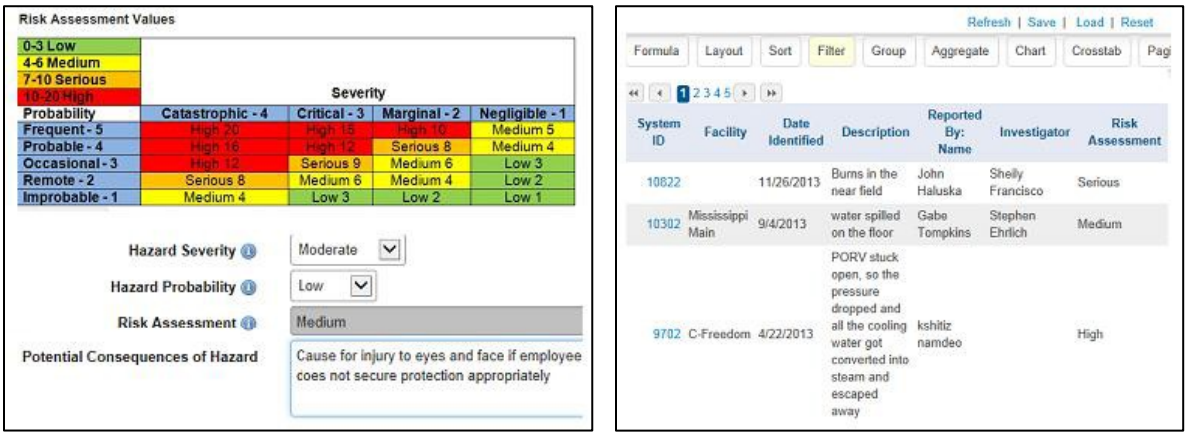


Figure B-10. Risk assessment matrix and hazard reporting

The incident module collects incident and near-misses data and analyzing trends using a suite of tools for incident investigation, communication, and reporting. Such tools can be used to perform root cause analysis through multiple dashboards (including incidents by root cause, contributing factor, day of week, month) to assess progress in reducing events over time, communicate critical incident information across the organization, or generate standard regulatory reports (by month, type, department).

The corrective actions module enables organizations to generate, track, and report on action plans for hazards, incidents, near misses, and various other safety events. Corrective and preventive actions may be the result of other safety activities, such as hazards, incidents, operational events, and internal and external audits. Multiple corrective actions can be linked to a single incident to generate a holistic view of the action plan. Email notifications can be sent to individuals when they are assigned a corrective or preventive action, and escalation emails can be sent to supervisors to monitor the status and completion rate of corrective actions. Finally, the corrective actions module allows safety managers to generate a variety of reports on action activity and followup, upload supporting documents, export data to other applications, and monitor corrective action metrics across the organization.

Figure B-11 shows examples of how IndustrySafe helps organizations monitor, track, and report on corrective actions.

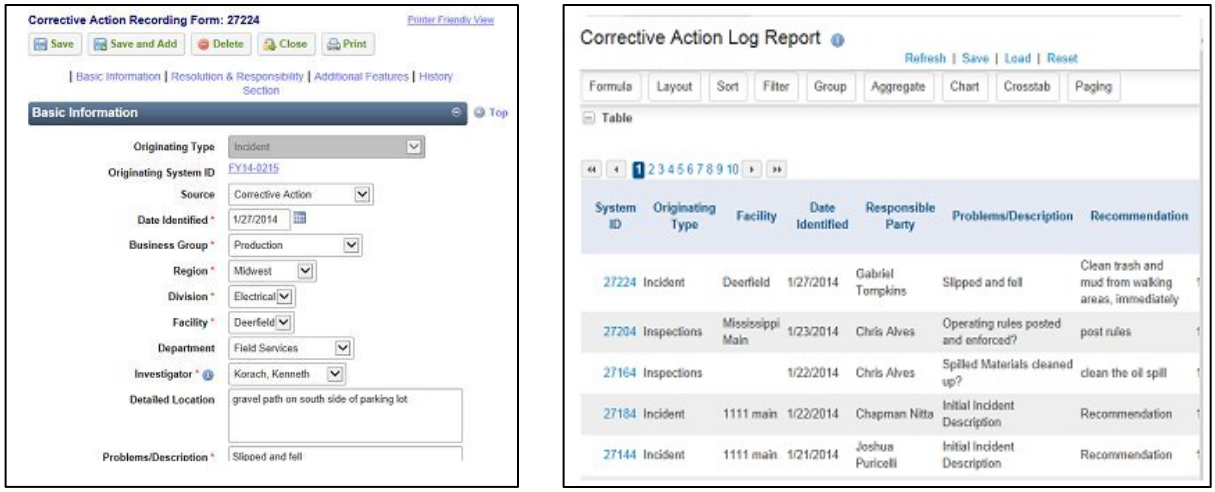


Figure B-11. Corrective action monitoring, tracking, and reporting

All three of the aforementioned modules use a dashboard module to view and analyze key hazard, incident, and corrective action metrics. Dashboards are configurable interfaces in which users can configure key metrics to be displayed in charts and graphs, and can add or remove filters, tabs, and panels for optimal usability. Dashboards are updated in real time as data are entered into other modules and allow users to perform an analysis to view underlying data. Dashboards can also be printed or exported into a report. For instance, incident dashboards can represent incidents by month, week, year, day of week, time of day, root cause, type, category, severity, status, and nature. The dashboard module focuses on the visualization and tracking of top indicators and safety metrics.

Figure B-12 shows examples of an incident pyramid, a radargram showing incidents by root cause, and a risk level indicator.

Figure B-12. IndustrySafe incident pyramid, incidents by root cause, risk level indicator, and various types of dashboards

LogicManager

LogicManager ERM software is composed of seven major elements: 1) risk taxonomy and resource library; 2) risk identification, assessment, and evaluation; 3) risk mitigation and control activities; 4) corrective actions monitoring, testing, measuring, and tracking; 5) risk analysis and ad-hoc reporting; 6) risk and compliance management; and 7) reporting and analysis dashboards [71],[72].

Risk taxonomy is the practice of naming, classifying, and defining relationships between resources, risks, goals, and operational processes in the enterprise. Risk taxonomy, in combination

with a common risk breakdown structure or a common operational risk event classification process, is an essential element to objectively and efficiently compare different types of risks across the enterprise. The taxonomy and resource library module allows organizations to create structured, centralized repositories of business processes, risks, goals, requirements, relationships with third parties, physical assets, data repositories, documents, tasks, people, policies, and use defined applications.

The risk identification, assessment, and evaluation module allows risk managers to adopt a holistic view of risk, prioritize resources, and focus on monitoring issues that will yield the greatest benefit to the organization. This module includes several risk identification, assessment, analysis, and reporting tools:

- A customizable root cause library in which key performance indicators can be defined, risks can be documented and managed, compliance and performance can be monitored, and emerging risks or new standards can be added as needed.

- A risk assessment assignment tool in which risks can be assigned to individuals for them to "assess risk on impact, likelihood, and mitigation effectiveness (assurance), evaluate if further mitigation is needed, document new or existing control and monitoring activities, and identify new or emerging risks" [71].

- A customizable, pre-populated, standardized risk evaluation criteria library with which accurate and actionable risk management can be performed based on the same standards, objectives, and assumptions.

- A risk assessment and analysis tool library in which information from various operational areas can be collected and used to make collective decisions about overall risk levels and severities, tolerance ranges can be set to estimate escalation requirements of individual risks, and risk-scenario analysis can be performed to help in making better decisions under uncertain risk conditions. Risk analysis tools further allow risk managers to view risk trends over time with respect to a risk reference point so that corrective actions can be taken when changes in the risk profile are identified to avoid exceeding acceptable levels.

- A results aggregation and reporting tool library in which risk managers can "examine and analyze risk assessments holistically to prioritize which risks and areas of the business are in the most need for mitigation activities, increased monitoring, and resources" [71]. Risk managers can choose from an array of graphical tools to provide both a top-down and a bottom-up view of risk across multiple dimensions and from a variety of reporting schemes to convey relevant risk information (e.g., heatmaps, flexible dashboards, canned reports, and ad hoc reports).

The risk mitigation, procedures, and control activities module is designed to define and document the lifecycle of all risk mitigation activities or corrective actions put in place across the organization. The goal is to create a repository of various documents and resources, such as:

- Financial, operational, and procedural activities
- Historical changes to the risk management plan

- Relationships between risk properties, corrective actions, performance indicators, and individuals involved in the resolution of each risk
- Issues and findings on control activities from identification to resolution of the associated risks
- Potential gaps and misalignment of activities across the organization

The corrective actions monitoring, testing, measuring, and tracking module features a LogicManager SMART risk monitoring process to link "robust testing, incident and issues management, issues, and business metrics collection to risks" [71]. Once corrective actions and monitoring activities have been defined, their ability to effectively and efficiently prevent risks, achieve operational goals, or meet compliance standards needs to be tested and verified. This is done through the interactive definition and use of key performance and control measures, which allow organizations to view trends and track progress in resolving risk over time. The incident and issues management capability allows risk managers to "capture events, evaluate incidents criticality, and assign respondents and workflows based on impact and regulations to facilitate cross-functional investigations" [71]. It further allows organizations to consolidate response procedures, manage investigations end-to-end, and report on trends, losses, recovery efforts, and related incidents" [71].

The risk analysis and ad hoc reporting module is powered by Actuate Corporation (now OpenText™ [83]), which founded and co-lead the Business Intelligence and Reporting Tools (BIRT) open source project. It allows end users to create personalized data visualizations that can be saved in a report and distributed automatically and at a custom frequency (weekly, monthly, quarterly).

The risk and compliance management module includes information about workflows, ad hoc approval processes, tasks, assigned individuals, due dates, comments, notifications and reminders, relevant mitigation documents, and access and permissions to facilitate the risk assessment, mitigation, and validation process, and provide a holistic framework for efficient and effective risk management across the organization.

Finally, the reports and dashboards module allows risk managers to connect information from various operational areas; identify vulnerabilities, gaps, and opportunities; prioritize business processes and risks; drill down and roll up risk assessments across the organization (perform top-down and bottom-up analyses); display risk trends over time to take actions before acceptable levels are exceeded; reveal systemic risks by tracking the number of times a given risk occurs and is assessed across the organization; and track progress on key measures for effective and efficient risk management success.

Figure B-13 provides examples of interfaces for each of the aforementioned modules: (a) risk taxonomy and resource library; (b) risk identification, assessment, and evaluation; (c) risk mitigation and control activities; (d) corrective actions monitoring, testing, measuring, and tracking; (e) risk analysis and ad-hoc reporting; (f) risk and compliance management; and (g) reporting and analysis dashboards.

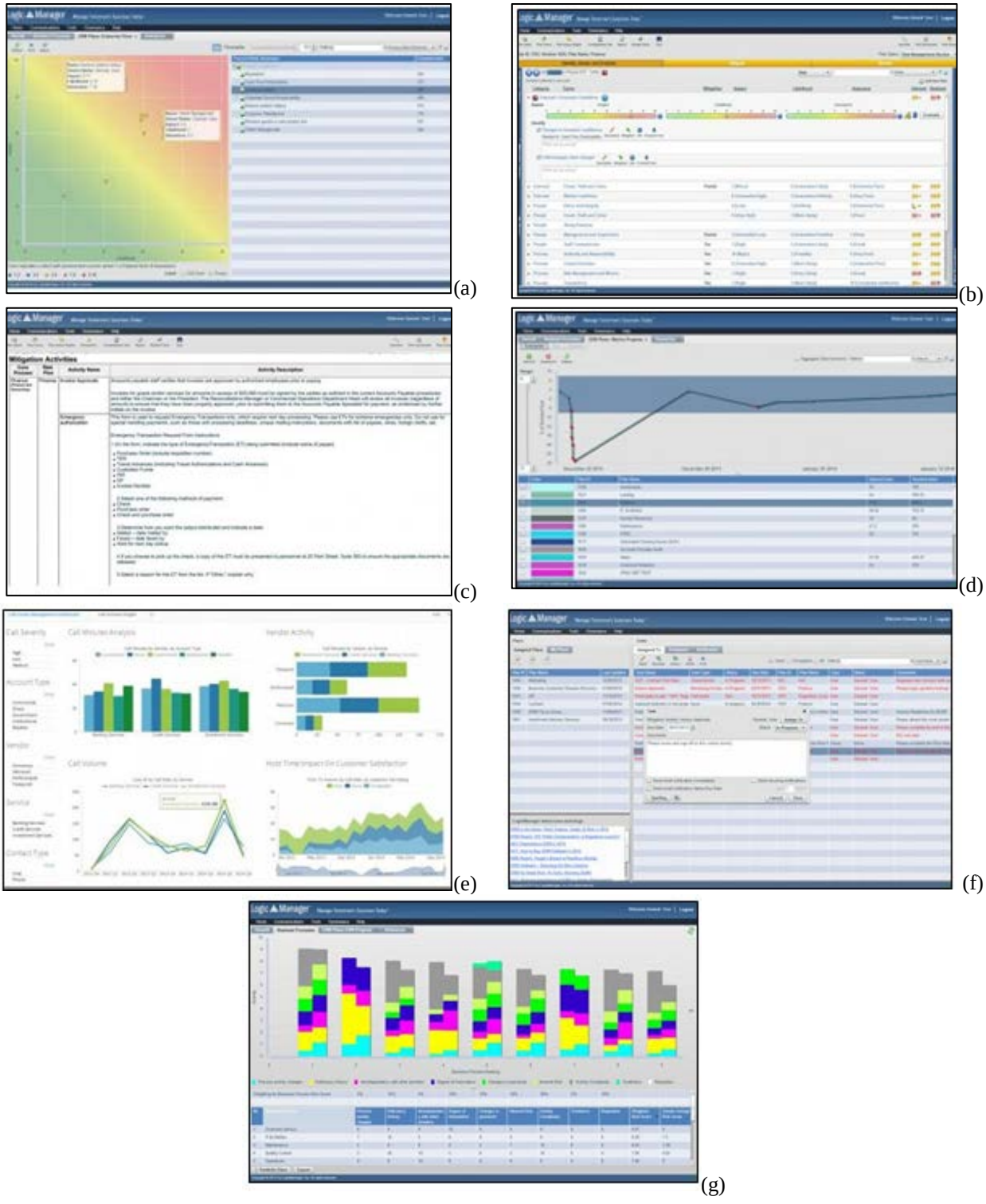


Figure B-13. LogicManager enterprise risk management modules

LogicManager ERM modules are combined with a policy management module, an audit management module, a compliance management module, and an incident management module.

The policy management module allows organizations to develop, review, approve, update, and archive policies, procedures, and operating standards. This implies scoring, assessing, and uncovering critical policies and procedures, which help delegate time and resources more efficiently across the organization. This further allows consolidating policies and procedures into a single library; tackling key tasks, updates, and reviews; and setting up permissions, custom workflows, email alerts, and notifications to assign ownership and responsibilities to competent personnel, and to monitor due dates or actions required. Finally, the policy management module enables managers to engage the right personnel to create, modify, review, and approve policy and procedure documents.

The audit management module allows organizations to schedule, plan, and execute audits. This involves identifying and tracking key audit dates, conducting risk assessments, using risk scoring to identify areas that require the most attention and resources, and generating reports on issues, findings, gap and exposure analyses, and other analyses for more efficient planning.

The compliance management module allows organizations to assess compliance to relevant standards and frameworks, document activities in place to meet each specific requirement, and report compliance levels and gaps.

Finally, the incident management module allows organizations to efficiently track the entire incident process from creation through severity assessment, identification of potential causes/sources, assignment of tasks to competent personnel, follow-up, response, and completion.

MetricStream

MetricStream provides organizations with the ability to "identify, assess, quantify, monitor, and manage their enterprise risk in an integrated manner" by aggregating "all risk management related data – including risks and their corresponding controls and assessments, results from individual assessments, key risk indicators, events such as losses and near misses, and issues and remediation plans – in a single solution" [73]. In particular, the MetricStream risk management solution provides an "integrated and flexible framework for documenting and assessing risks, defining controls, managing assessments and audits, identifying issues, and implementing recommendations and remediation plans" [73]. The MetricStream risk management solution offers a variety of tools for risk assessment and analysis, controls design and assessment, internal audits management, issue management and remediation, and risk monitoring [74].

For instance, risk assessment and analysis are supported by risk heat maps and configurable risk calculators, methodologies, and algorithms to provide a holistic view into the organization's risk profile and to help prioritize response strategies for an optimal risk-to-reward ratio.

Controls design and assessments are performed once risks have been identified and prioritized, and it is necessary to mitigate them. A series of tools allows risk managers to link risks and associated controls to relevant policies and procedure documents, design assessment plans to ensure the effectiveness of current corrective actions (using predefined criteria, checklists, and scoring, tabulating, and reporting mechanisms), assign tasks to individuals based on their roles

and responsibilities, and create a repository of all risk assessments, including remedial action status, tested risk controls, and assessment results.

Internal audit management tools support a variety of activities related to the internal, operational, and quality audits lifecycle, such as audit planning and scheduling, development of audit plans and checklists, field data collection, development of audits reports and recommendations, review of audit recommendations, and implementation of recommendations. This is done through the use of "built-in remediation workflows, time tracking, email-based notifications and alerts, risk assessment methodologies, and offline functionalities" [73].

Issue management and remediation tools allow the identification, documentation, investigation, prioritization, remediation, and tracking of various types of external events, such as loss events or near misses.

Finally, risk monitoring dashboards allow the user to access the underlying details of the data and to track items such as the risk profile of the organization, the control ownership of risk by various individuals within the organization, the assessment plans, the remediation status, and the global efficiency of the risk management process by displaying real-time information, and allowing end users to generate standard, ad hoc, or scheduled reports.

PRISM Safety

PRISM Safety claims that its PRISM software is "the only integrated Quality, Safety, and Risk Management tool that automatically monitors potential risk and sends alerts to the relevant people" [88].

The PRISM software is composed of ten modules:

1. The proactive risk alerts module automatically notifies management when the system identifies a change in a given risk level.
2. The enterprise-wide access module provides access to the system to every member of the organization.
3. The risk assessment matrix and risk adjuster module automatically calculates the present operational risk based on an initial risk assessment, previous occurrences, and time period of occurrences.
4. The integrated email system automatically alerts relevant individuals when a change in risk assessment, audit, or corrective action status (due, overdue, or completed) is made or when an action is required.
5. The data formalization module stores information from meeting agendas, minutes, audit reports, safety suggestions, accident reports, flight crew reports, and ground staff reports in a single package easily accessible to everyone in the organization.
6. The reporting module is designed to automatically generate reports from available data entered into the system, to store these reports in a database, and to instantaneously send them to management for review.

7. The global access module ensures that management can access the system from anywhere, provided they have an Internet connection.
8. The trend analysis tool is designed to identify engine trends for maintenance purposes.
9. The hazardous events management process (HEMP) module features a variety of bowties to manage hazards to an acceptable risk level.
10. The proactive risk assessment and management of change module allows for both proactive risk assessment requirements and day-to-day risk profiling by automatically generating and managing corrective action requirements and a risk action plan.

Q5 Systems SMS Risk Management

The Q5 Systems SMS Risk Management module is part of the Q5 SMS solution [90]. It provides organizations with the ability to proactively identify risks and hazards; assess their severity, probability of occurrence, and impacts; decide on an action plan; and evaluate the results. The Q5 Systems SMS Risk Management module further allows users to create a registry for recording potential and actual risks and hazards. The Q5 Systems SMS Risk Management module works in collaboration with the Action Tracking module, the Event Reporting module, and the Investigations module for improved risk mitigation and monitoring.

The Q5 Systems SMS Action Tracking module allows users to identify, prioritize, manage, and track any recommended, corrective, and preventive actions that ensure compliance with all applicable standards and regulations. It provides the ability to perform root cause analyses, full investigations, or complete cost-benefit analyses on specific actions of interest, and to automatically send escalation notifications, reminders, and action status updates to the relevant people in the organization.

The Q5 Systems SMS Event Reporting module consolidates and stores information concerning potential risks, hazards, incidents, and accidents in a reactive manner to ensure that future incidents are containable and preventable.

The Q5 Systems SMS Investigations module provides the tools to effectively and efficiently investigate significant safety event occurrences across the organization, such as determining the potential causes of an event or the parameters triggering it to prevent this event from occurring in the future. This module further allows the collection and storage of investigation information, the generation of investigation reports, and the automatic generation of notifications concerning investigations and their results.

Rivo

The Rivo ERM software provides a platform for identifying, categorizing, analyzing, mitigating, controlling, and reporting on risk across the organization [96],[97]. Rivo's ERM is composed of several modules designed to deal with risk and hazard management, incident reporting and management, actions and tasks management, audit and inspection management, quality management, document and policy management, business continuity management, and training

and competence management. Among these modules, audit and inspection management, quality management, document and policy management, and business continuity management are also part of Rivo's SMS and will be discussed in section 9.11. Only the risk and hazard management, incident reporting and management, actions and tasks management, and training and competence management modules are detailed in this section.

The risk and hazard management module allows organizations to deal with and report on risks, hazards, and non-conformances, namely to:

- Identify, record, and monitor risks, hazards, and non-conformances across the organization through audits, inspections, or other data collection tools
- Assess these risks, hazards, and non-conformances according to a set of key evaluation criteria
- Allocate and track mitigative (corrective and preventive) actions to reduce the probability and consequences of these risks, hazards, and non-conformances
- Holistically analyze risk and trending across the organization through a variety of real-time dashboards that aggregate multiple data sources to allow top-down analysis of risks, hazards, and non-conformances
- Generate reports on the lifecycle of risks, hazards, and non-conformances through the use of pre-configured or customizable reports

The incident reporting and management module is designed to analyze incidents and near misses, namely to:

- Identify and characterize incidents, observations, near misses, and other events
- Alert relevant individuals about incidents and near misses based on severity, category, and type, and on the individual role and responsibilities
- Review and investigate identified incidents through trend and root cause analysis to reduce incident frequency of occurrence
- Automate the escalation and reporting process
- Report on and communicate the results of the investigation to all members in the organization

The actions and tasks management module allows organizations to create, allocate, and track actions and tasks, namely to:

- Create corrective and preventive actions or tasks in response to a risk, hazard, or non-conformance identified through an inspection, audit, or other review process
- Assign tasks to relevant individuals within the organization and ensure continuity of the action plan
- Track the status of actions and tasks, and get automatic notifications, reminders, and potential escalations when actions or tasks are due, overdue, completed, or changed

The training and competence management module allows organizations to "automate the management of training and competence records, licenses to operate and qualifications" [96]. This ensures that management has a complete view of the training and competence status of everyone

in the organization by person, location, compliance status, roles, and responsibilities. This module allows managers to create training records for each individual, populate a configurable competency matrix summarizing qualifications, competencies, licenses, roles and responsibilities, and get automatic notifications of training results, expiring licenses, and training or refresher course completion.

The four aforementioned modules call upon the Rivo Analytics software to perform "big data" operations such as "capture, integrate, monitor, automate, action, analyze and report" for "smarter and faster decision making." "Rivo Analytics is a sophisticated, yet user-friendly, multi-dimensional analysis platform that enables users to slice, dice, drill down, adjust, trend and plot operational risk and performance data at will, following a fully transparent, intuitive and sequential process" [96]. Rivo Analytics works in collaboration with Rivo Geo-Mapping, which allows large organizations to map incidents and events (near misses, occurrences, observations) based on geographical locations, and uncover patterns and trends so as to improve enterprise risk and performance management. Finally, Rivo provides the means to aggregate large amounts of data across the organization and use the resulting information to predict safety, security, and sustainability risk and performance events before they occur. Rivo predictive analytics allows organizations to "transform data into predictive insights" to "detect and prevent threats/risks" as and before they actually occur, and to "perform high intensity statistical analysis" [96]. Figure B-14 provides examples of displays for trend and predictive analysis results from Rivo Analytics.

Figure B-14. Rivo analytics

Aviation SMS Pro Risk

SMS Pro Risk Management module is composed of 11 sub-modules designed to efficiently deal with and report on risk [109],[110].

The hazard and risk register module uses the SMS Pro Proactive Hazard Analysis Tool (PHAT) to create a list of hazards per operation and per risk category, including identified hazards, associated risks, risks assessments, responsible individual, mitigation measures, due date, review date, and closing date. Figure B-15 gives examples of hazard and risk registries generated by the SMS Pro PHAT tool.

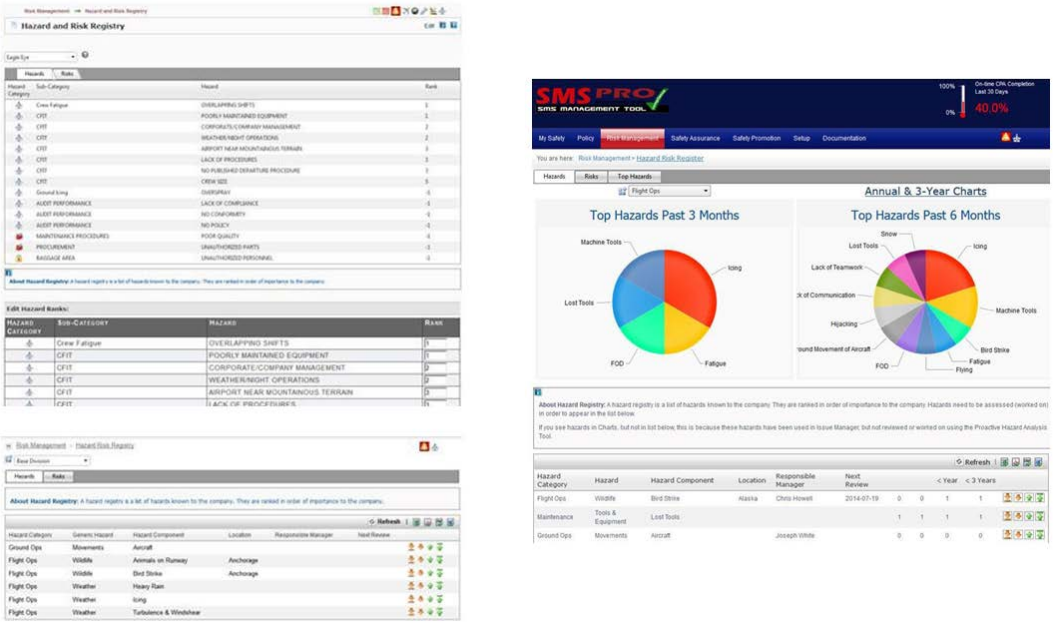


Figure B-15. SMS Pro hazard and risk registry

The risk analysis charts module allows risk managers to easily review risks and identify challenges. SMS Pro features a series of charting tools to determine the most time-consuming and costly issues for the organization, to analyze risks at all levels by drilling up and down into the relevant data, and to filter data to get a customized holistic picture of risk across the organization. Reports can also be generated to display the types of issues, processes involved, identified or potential root causes, associated risks and hazards, associated human factors (if any), relevant key performance indicators, status of risk mitigation activities (open, closed, in progress, reviewed), and responsible parties. Figure B-16 provides an example of a risk analysis pie chart from the SMS Pro risk analysis charts module.

Figure B-16. SMS Pro risk analysis charts

The financial risk analysis charts module is similar to the previous module but is focused on the effects of managing risks concerning financial costs. The goal is for managers to identify the types of issues that are costing them the most time and money to mitigate, and to make effective financial

analysis recommendations. Figure B-17 shows an example of a financial risk pie chart from the SMS Pro financial risk analysis charts module.

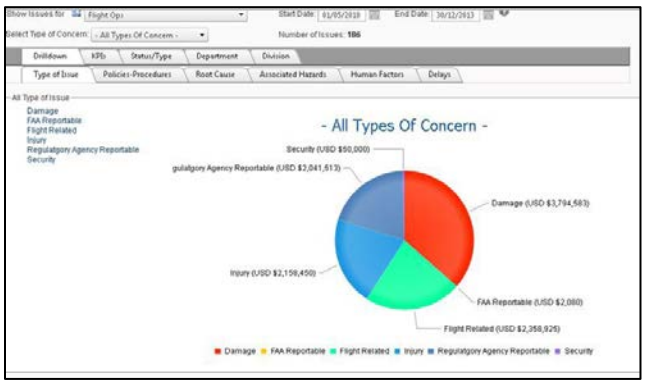


Figure B-17. SMS Pro financial risk analysis charts

The trending charts module is designed to collect data across the organization and identify patterns or trends in the associated information. It is based on a variety of charts that typically show changes in one or more variables over time (weeks, months, quarters, years). Some filters can also be applied to zoom in on a specific category of data related to safety, quality, performance, or compliance. Figure B-18 gives examples of trending bar charts from the SMS Pro trending charts module.

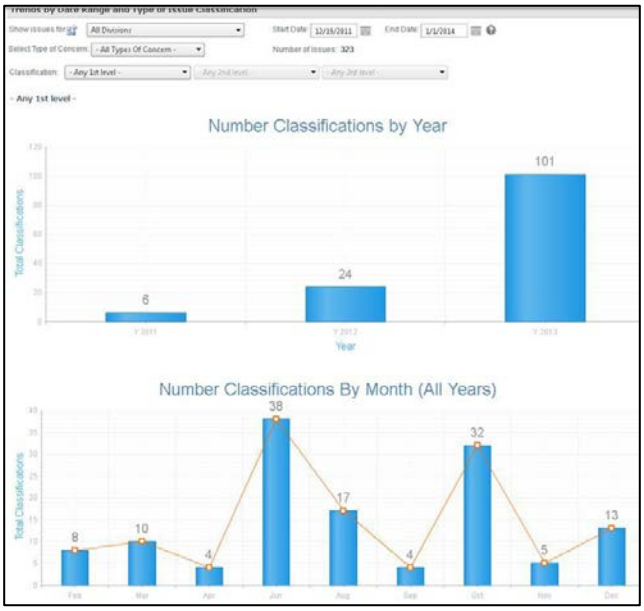


Figure B-18. SMS Pro trending charts

The proactive hazard analysis module allows organizations "to review hazards, manage risks and determine control and recovery measures proactively" [110]. It makes use of the SMS Pro PHAT tool, which incorporates a predefined Operational Risk Profile (ORP) corresponding to the organization. The ORP includes hazards, hazard categories, hazard subcategories, and worst potential hazard consequences, and is used to help risk managers better allocate risk management

strategies. Figure B-19 provides an example of how proactive hazard analysis is performed by SMS Pro Risk Management module.

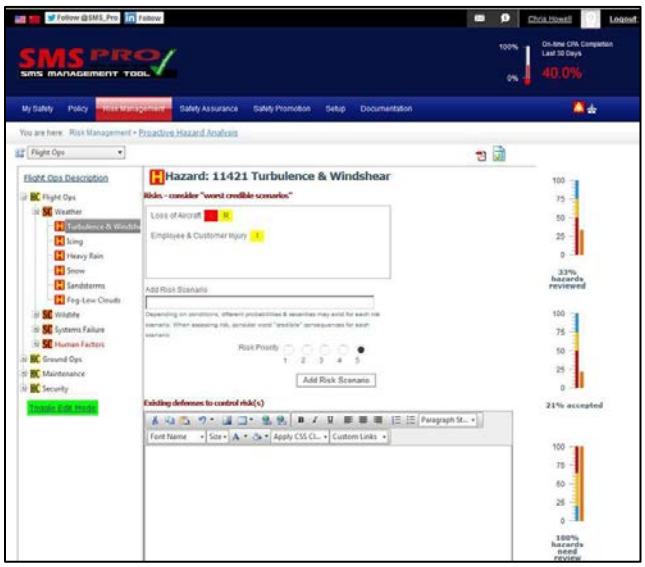


Figure B-19. SMS Pro proactive hazard analysis

The Corrective Preventive Actions (CPA) manager module "allows safety managers to monitor corrective actions progress and easily identify bottlenecks" [110]. The CPA manager features a variety of filters to investigate corrective actions, such as by division and status, and through text search. Figure B-20 shows an example interface for the SMS Pro CPA Manager.

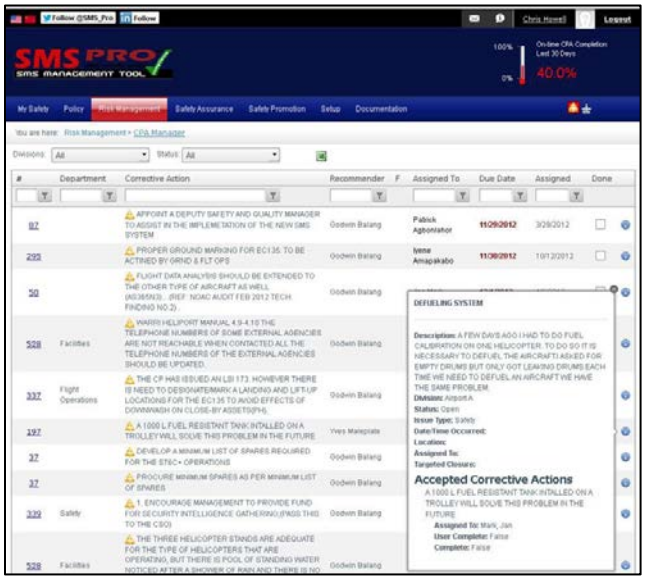


Figure B-20. SMS Pro corrective preventive actions manager

The data analysis and export module allows risk managers to investigate and export data to various formats. For instance, risk managers can categorize and sort hazards, risks, and incidents; conduct

ad hoc queries on reported hazards, risks, and incidents; and export relevant results to Microsoft® Word®, Excel®, and PDF. Figure B-21 gives an example of how risk data can be investigated and exported to various formats from the SMS Pro data analysis and export module.

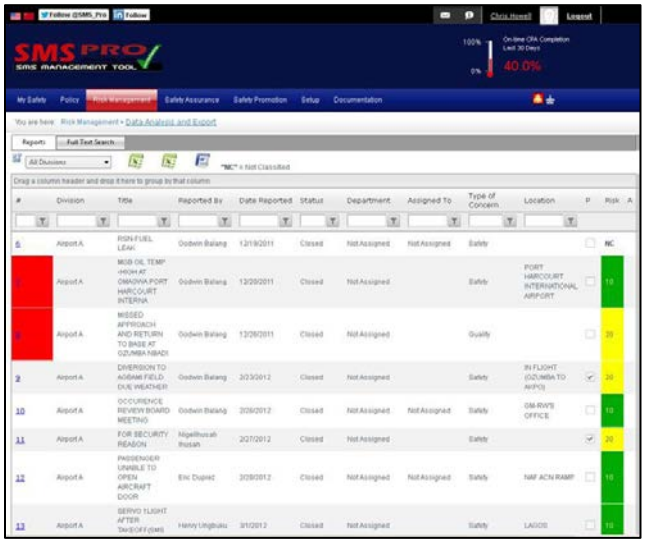


Figure B-21. SMS Pro data analysis and export

The management of change module is composed of two submodules: 1) a complex one dealing with tasks, detailed hazard analysis, and structured workflow specifically geared toward managers; and 2) a much simpler one designed for every type of user. The management of change module allows organizations to document processes and activities associated with a change in management (whether permanent or temporary) such as adding a new operation or purchasing a new aircraft/rotorcraft, and to define who is in charge and what areas of operations are being affected. Figure B-22 gives an example of how to create a management of change activity.

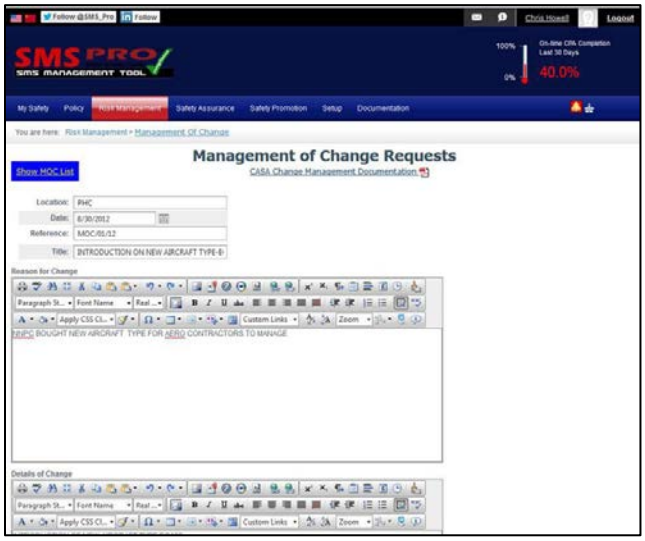


Figure B-22. SMS Pro management of change

The issue manager module allows responsible parties to "conduct risk assessments, clarify issues, manage corrective actions, conduct investigations, and more" [110]. Hazard risk management consists in identifying, categorizing, assessing, prioritizing, minimizing, monitoring, and controlling the impacts of risks to the organization. SMS Pro issue manager walks risk managers through the process of identifying and reporting threats, incidents, or non-compliance (more generally called "events"); assessing the vulnerability of critical elements in the organization; determining the consequences of reported events; classifying reported events; identifying ways to reduce risks and implementing relevant corrective actions; prioritizing risk reduction measures; communicating lessons learned; and analyzing data to focus resources and personnel. Reported events can come from public issue reporting in the organization, paper reports, email reports, system audits, and gap analyses. Figure B-23 provides an example risk assessment interface from the SMS Pro issue manager module.

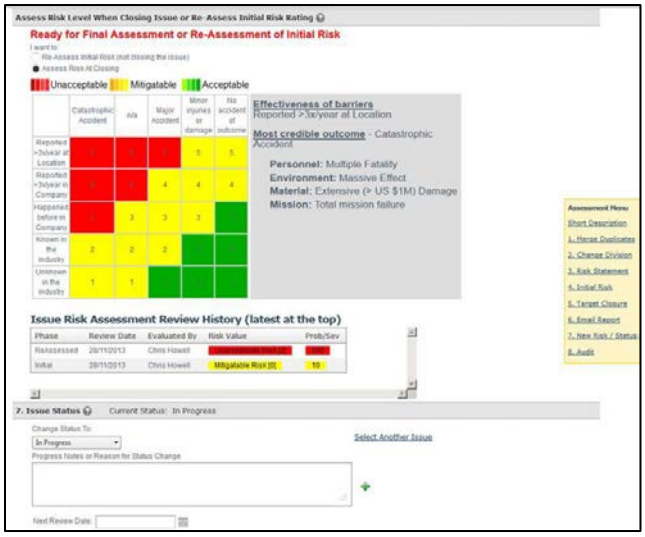


Figure B-23. SMS Pro issue manager

The custom report viewer module offers risk managers the choice of six different reporting templates. Figure B-24 shows an example of how a risk manager would create a custom report from available templates in the SMS Pro custom report viewer.

Figure B-24. SMS Pro custom report viewer

Finally, the classification reports module allows risk managers to generate ad hoc reports and filter reported events by classification types (such as types of issues, human factors, business practices, proactive hazards, and operations), by operational area, by date (start or end dates), and by category (safety, quality, performance, compliance). Figure B-25 gives an example classification report from the SMS Pro classification reports module.

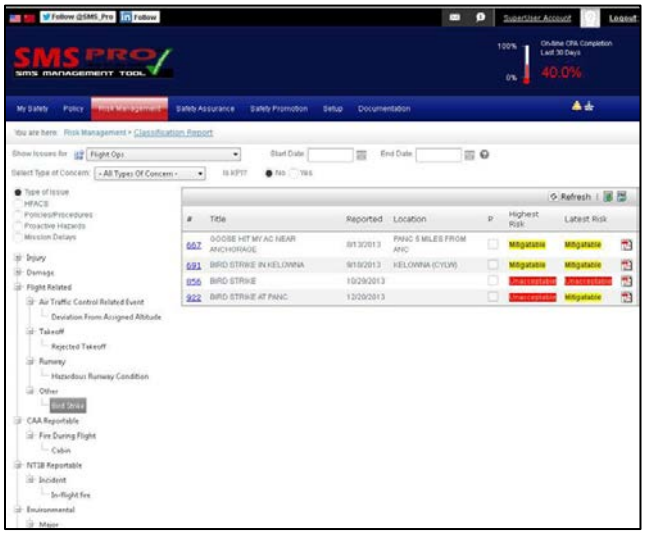


Figure B-25. SMS Pro classification reports

Synergi Life

The Synergi Life risk management module is designed to support each stage of the risk assessment process at the enterprise, operational, project, security, safety, environmental, and supply chain levels. It "provides a scenario-based evaluation of risk level as a function of likelihood of occurrence and potential severity of impact towards the organisations objectives. Risks are evaluated both on an inherent and residual basis" [112]. The Synergi Life risk management module helps risk managers assess whether to accept, avoid, reduce, or share the risk, depending on the organization's risk appetite. Then, corrective actions can be defined and evaluated to determine their ability to reduce the potential impact and the probability of occurrence of a given risk, and to decrease the time and cost to mitigate existing or potential risks. Finally, risk level is constantly monitored through the use of statistics, trending, and real-time analyses. The Synergi Life risk management module, shown in Figure B-26, facilitates risk-based decisions by:

- Building a consistent best practice risk management process across the organization
- Efficiently visualizing risk exposure and barrier effectiveness through bowtie diagrams
- Demonstrating compliance with applicable procedures, regulations, and standards to ensure traceability and accountability
- Improving visibility and effects of risk management activities
- Enhancing emergency and contingency planning
- Clarifying impact of decisions and activities on overall risk level

- Saving time and money by better allocating resources

Figure B-26. Synergi Life risk management module

The Synergi Life risk management module can be used in conjunction with the incident management module, which is designed to deal with incident and near misses, including "full investigation, risk evaluation, loss causation modelling [*sic*] and action management process" [113]. Typically, incidents and near misses are categorized according to their risk levels through the use of a risk matrix. Then, potential losses and consequences are documented, potential causes are determined to facilitate a root cause analysis, and preventive, corrective, or temporary actions are defined with associated due dates and responsible parties. Email notifications ensure that both risk managers and responsible individuals get appropriate alerts, reminders, and information concerning the overall status of the risk management process or their respective mitigative actions for followup and investigation. Relevant documents are attached to identified incidents or near misses and their corresponding mitigative actions and responsible individuals. Finally, relevant risk and incident data can be aggregated from multiple operational sectors and analyzed holistically to recognize trends and ensure compliance with applicable regulations, procedures, and standards. Results of such analyses are displayed in a number of flexible ways or exported to Microsoft Excel, Word or PowerPoint™ for further analysis and are communicated to relevant people via paper reports.

Xactium Cloud Solutions

Xactium cloud solutions [124] risk manager is typically used by "large organizations […] to manage project, business unit, enterprise or operational risk" [125]. It is designed to help risk managers efficiently manage the entire risk management process, including risk identification, risk assessment, risk monitoring and control, and risk analysis and reporting.

Risk identification deals with the identification and recording of both existing and potential risks that impact the organization at all levels (project, enterprise, operations) and the identification and recording of the potential impacts and causes of these risks.

Risk assessment addresses the multiple components necessary for an efficient risk assessment process at the enterprise level, namely:

- Establishing risk evaluation criteria, such as custom or standard scoring schemes and risk matrices, and impact categories that matter to the organization
- Quantitatively and qualitatively assessing inherent, residual, and target risk levels, both before and after corrective actions have been implemented, to capture the organization's risk tolerance, including real-time trends and statistics
- Creating workflows to notify responsible parties of relevant risk assessment variables, including due date, and required activities
- Aggregating risk assessment results across the entire organization by category, hierarchy, and financial value

Risk control and monitoring consists in defining controls and their linkage to the relevant risks; defining key risk indicators and their linkage to the relevant risks, and tracking and monitoring their values over time; establishing key control indicators to track their efficiency at preventing risk events; and capturing and tracking risk events and incidents, and notifying responsible individuals of their occurrence.

Risk analysis and reporting is meant to gain insight into key risk data, trends, and activities, and to produce relevant document, trend, and data reports. The goal is to track the impact of mitigating activities using interactive heat maps, analyze the rating of all risks and the values of key risk indicators and key control indicators over any period of time, get a holistic view of all risk data through a variety of charting options, and generate and distribute various types of automatic, standard, or custom reports from relevant risk data to relevant people. Figure B-27 gives examples of tools for risk assessment, mitigation, analysis, and reporting featured in the Xactium risk manager module.

Figure B-27. Xactium cloud solutions risk manager

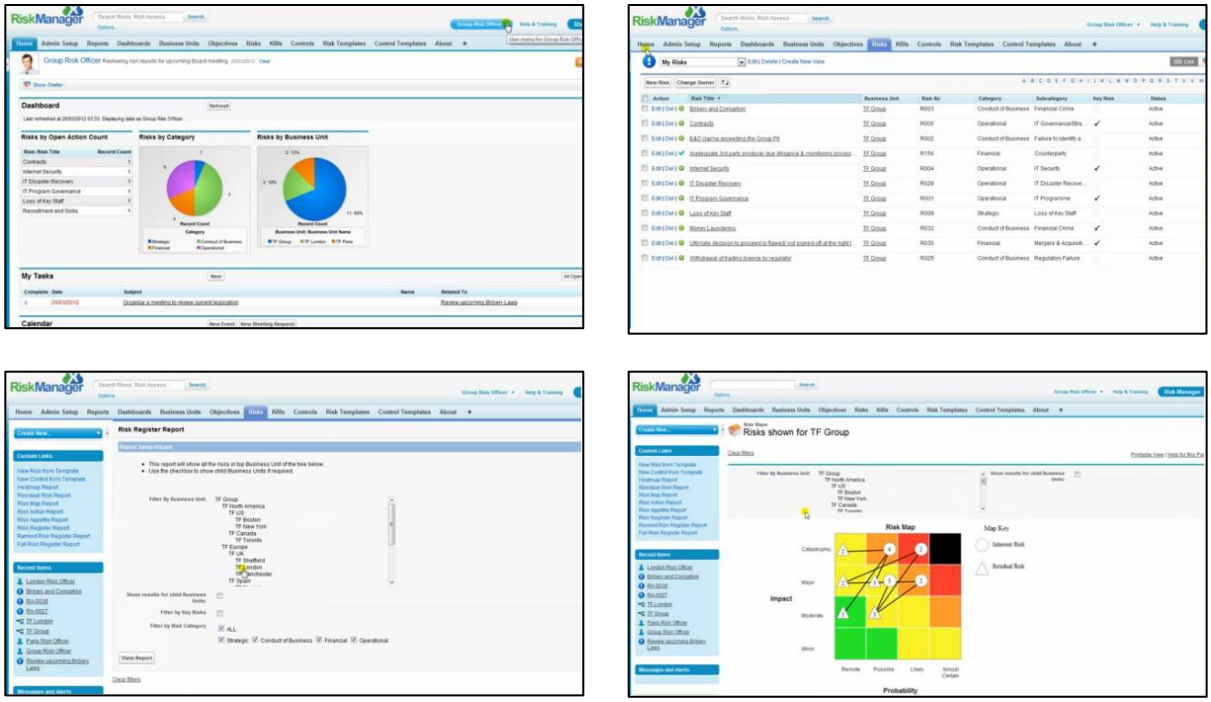


Figure B-27. Xactium cloud solutions risk manager (continued)

The Xactium risk manager can be used in conjunction with the Xactium incident manager to capture, track, and monitor incidents, near-misses, and risk events and their respective corrective actions. Xactium incident manger is designed to evaluate the criticality of an incident and its associated potential root causes; automatically assign responsible parties and put in place workflow rules for managing the incident lifecycle; create and track mitigating actions necessary to resolve the incident; and gain an overall understanding of current incidents and the status of their mitigation through a series of dashboards and reporting tools. Finally, the Xactium incident manager supports real-time management of risk events, incidents, and near-misses as they arise, including automatic filtering by severity, operational area, functional area, and location or custom filtering, and email updates and notifications to keep relevant individuals informed about identified issues. Figure B-28 provides snapshots of incident management tools used by the Xactium incident manager.

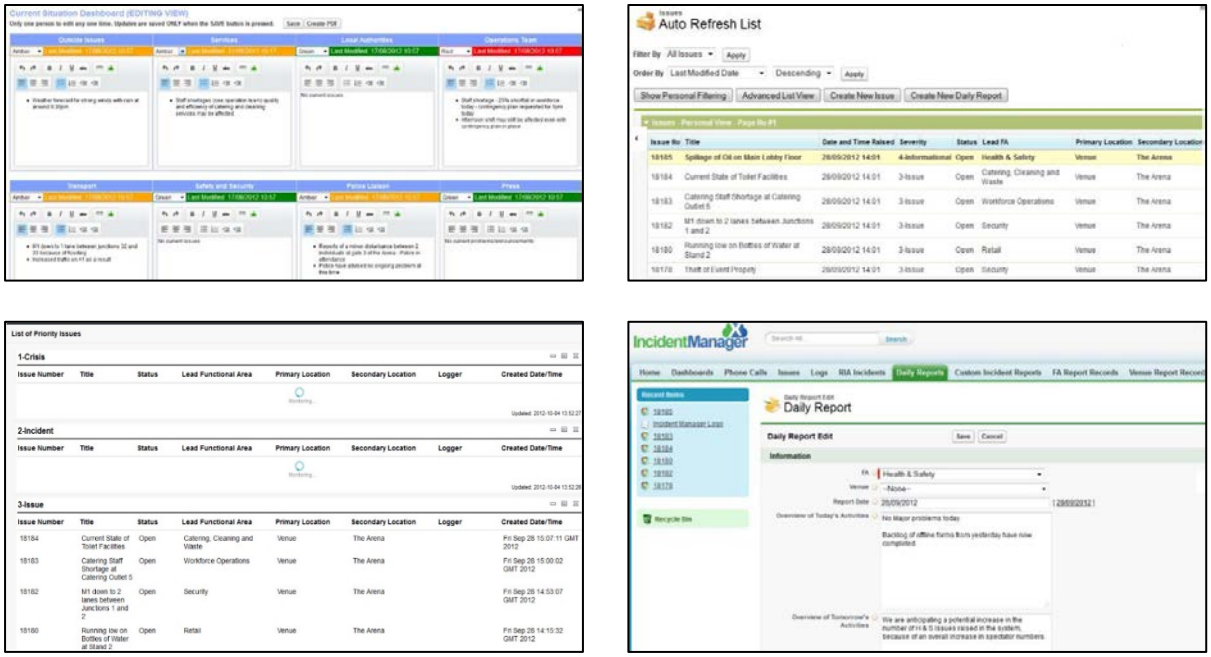


Figure B-28. Xactium cloud solutions incident manager

360factors™

Predict360™ ERM software provides organizations with a fully integrated solution designed to minimize risk and make better informed strategic decisions [86]. It enables organizations to manage risk at the enterprise level. This implies identifying, quantifying, mitigating, and monitoring risks, and assessing their operational, environmental, financial, legal, and safety impacts and probabilities of occurrence. Predict360 ERM combines risk assessment, mitigation, and management with corrective actions management, management of change, audit management, and compliance management to help assess risks in all relevant operational areas, continuously measure the effectiveness of mitigative actions, create and task corrective actions from risk analysis results, and monitor the effects of changing requirements on the corresponding risks, mitigative actions, audits, and tasks.

Predict360 ERM can be used in conjunction with Predict360 operational risk software [87] to help organizations create a risk culture, improve the integration and communication of risk exposure across the organization, reduce damage from risk events, and enhance operational performance. Predict360 operational risk software features various tools designed to collect, analyze, manage, and report on operational risk events, namely:

- Integrated framework for key risk identification, analysis, prioritization, and reporting
- Data collection concerning incidents, risks, and recommended actions
- A centralized repository of risk management processes and controls
- Graphical dashboards for risk assessment, risk analysis, and risk mitigation and control
- Analytical reporting for a holistic view of risk exposure and gaps, including qualitative and quantitative trending metrics

- Process workflow with integrated risk management methodology to create a risk-based culture
- Risk assessment surveys for audit-based risk assessment

Figure B-29 shows some snapshots of how risk management is performed using Predict360 ERM and operational risk software.

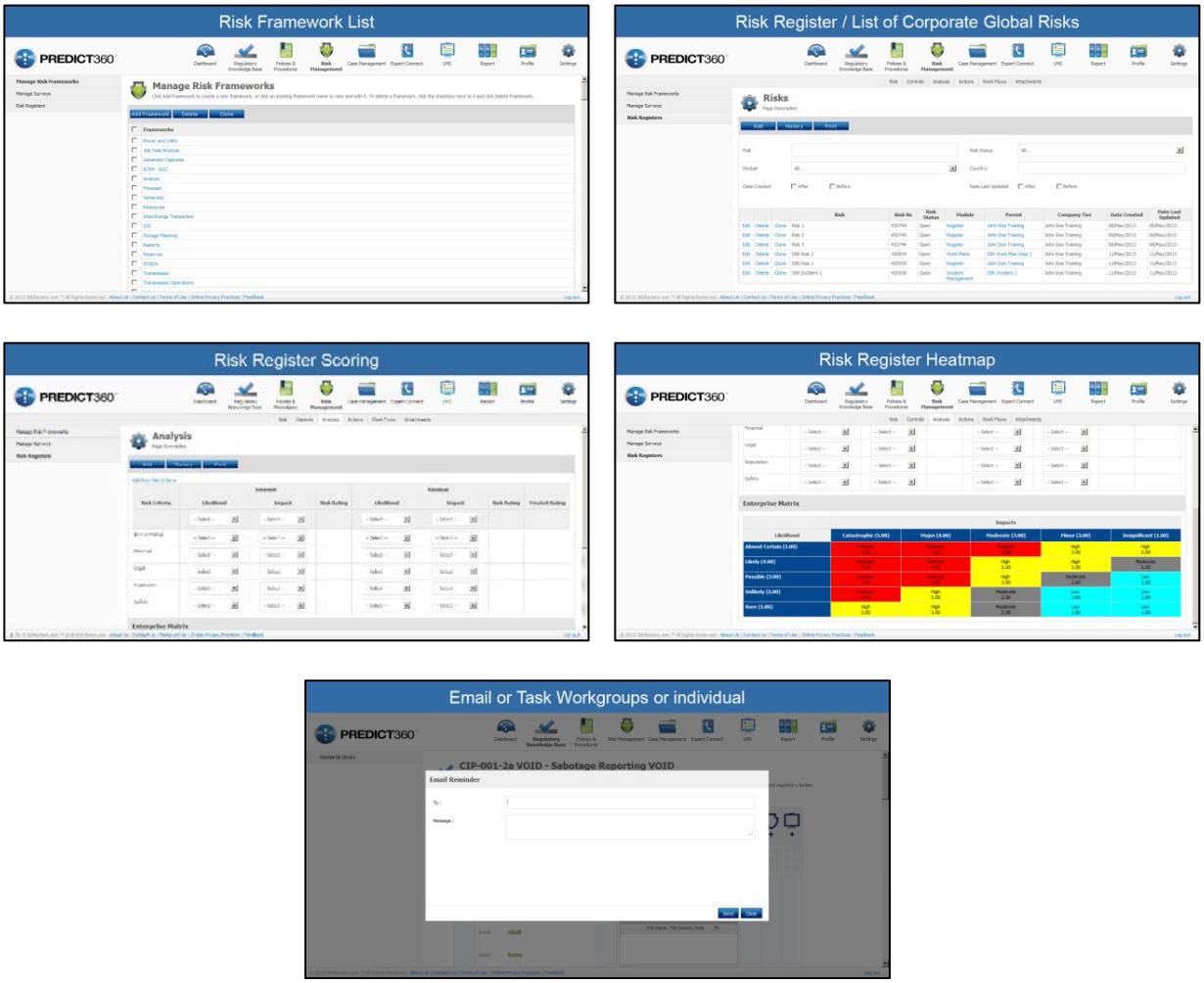


Figure B-29. Predict360 ERM software and operational risk software

AeroSDB

AeroSDB Safety Management System (SMS) provides a means to record hazards, occurrences, incidents, and other risk events; investigate those events to determine the relevant root causes and define corrective and preventive actions to mitigate further occurrences of the same or similar events; collect, store, and analyze risk data so that trends can be identified and further preventive actions can be implemented; and generate reports so that management is kept informed of relevant safety information [1],[2]. Figure C-1 shows two snapshots of AeroSDB SMS. AeroSDB features include:

- Recording of hazards, occurrences, incidents or other risk events
- Monitoring of occurrences for trends
- Investigation of recorded risk events
- Automatic generation of various types of reports
- Recording of all costs associated with an occurrence
- Creation, assignment, and tracking of recommendations and corrective actions
- Risk analysis
- Graphical representations of occurrences by risk factor or other custom filtered items
- Attachment of images, emails, or other types of documents to investigation reports

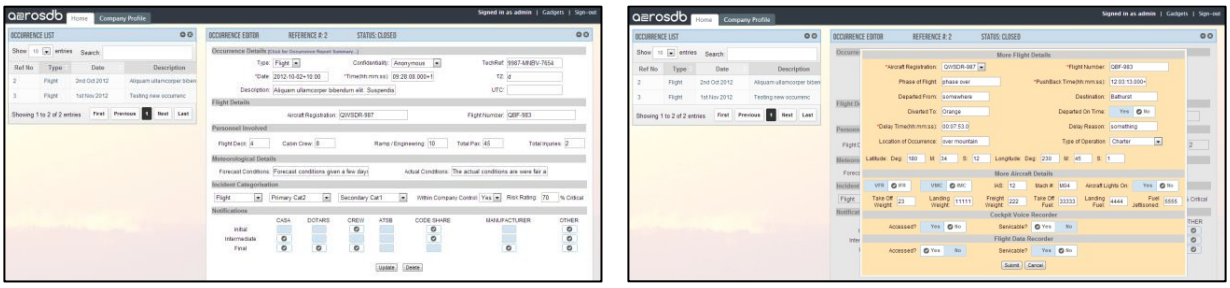


Figure C-1. AeroSDB safety management software

Avinet Air Maestro®

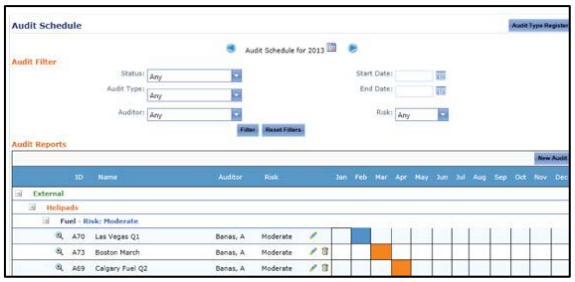
Avinet Air Maestro SMS is composed of several components, as follows [9].

- An operational risk assessment module, which allows risk managers to create risk assessment forms to calculate the risk associated with a given task and make informed decisions about whether to continue the task
- A rostering module, which keeps a list of all personnel, tasks assigned, work practice controls, versioning, and alerts or notifications
- An audit management module, which enables the planning, scheduling, and management of audits, including assignment and tracking of corrective actions to relevant individuals

- A document library module, which stores and monitors the distribution of and the access to all operational documents across the organization, including document receipt and opening
- A hazard register module, which enables the identification and analysis of hazards, and the management of associated risks and mitigative actions
- A safety statistics and charts module, which provides an overview of the safety events that occurred in the organization over time
- A reporting wizard module, which enables the generation of customizable and comprehensive analysis and trending reports on available operational and safety information
- A safety reporting module, which allows management and authorized personnel to investigate and analyze safety events and to review and approve incident resolution
- An integrated alerts module, which notifies relevant personnel about updates and required actions concerning hazards, risks, audits, operational documents, safety, and reports based on pre-defined criteria
- A work practice management module, which allows the creation of controls for shift, duty hours, rest periods, and work patterns
- A recency management module, which records currency requirements for all personnel and assets across the organization
- A training and checking module, which allows managers to create and distributes exams for compliance or training, and then to collect and analyze results and to establish trends
- A personnel management module, which manages and monitors personnel details, training, certificates, licenses, qualifications, and work practice compliance
- A timesheets module, which allows managers and relevant individuals to monitor compliance with work practices within the organization and to automatically notify personnel to complete or submit reports when controls are exceeded
- A scheduling module, which assigns tasks to qualified personnel
- A Fatigue Audit InterDyne® and Prior Sleep Wake Model module, which monitors personnel fatigue and its relationship to safety events

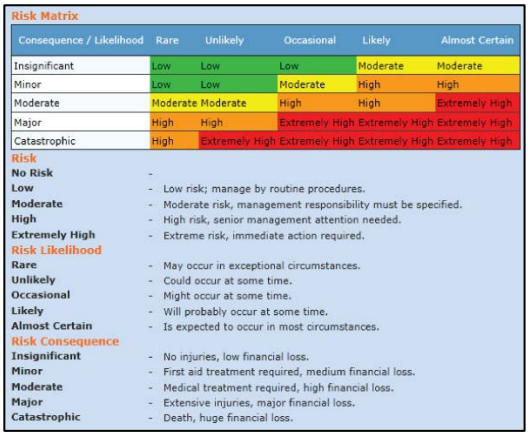
Some examples of are provided in Figure C-2: (a) rostering module; (b) audit management module; (c) risk assessement matrix; (d) training and checking module; (e) document library; (f) global reporting module; (g) hazard register module; and (h) safety reporting module.

(a)



(b)

Figure C-2. Avinet SMS software



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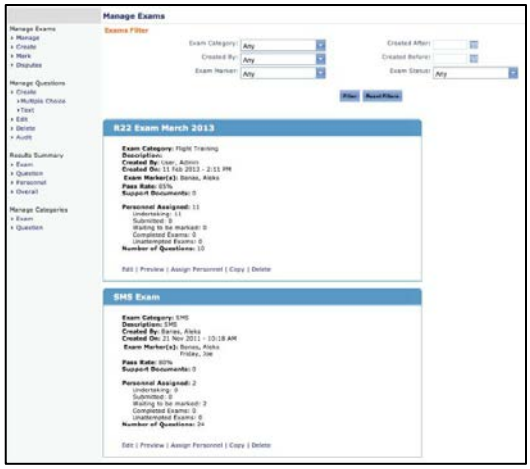

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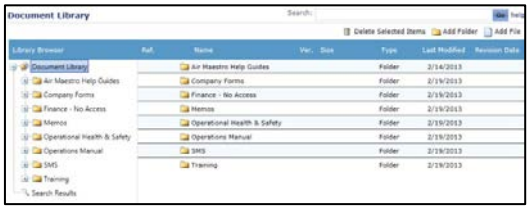

(e)

(f)

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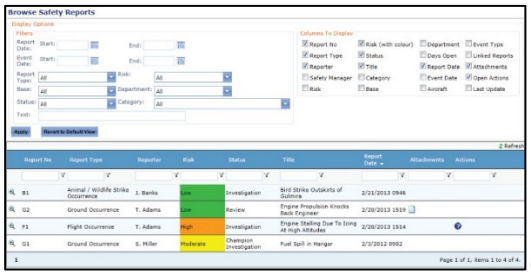


(h)

Figure C-2. Avinet SMS software (continued)

Mitratech AVIATION SMS

Mitratech Aviation SMS Software, called CMO Compliance [77], is designed to optimize data collection and provide real-time reporting capabilities on safety, quality, performance, incident or occurrences, regulatory compliance, and action management. It is composed of the following eight modules. A snapshot of the CMO Compliance software is shown in Figure C-3.

1. Audit and assessment module including audit management and action management
2. Incident management module including incident identification, root cause analysis, and mitigative action tracking
3. Risk management module including risk register, risk assessment, management of change, documents and policies library, meeting management, and hazard analysis
4. Compliance management module including legal obligations, permits and approvals tracking, and action management

5. Training and compliance module including training records, competence management, and standard operating procedures (SOPs)
6. Environmental module including monitoring and measuring of emissions, environmental incidents reporting, environmental obligations and responsibilities management, permits and approvals tracking, and stakeholder management
7. Health and safety module including occupational health, industrial hygiene, crisis management, document control, objectives and targets, emergency response, meeting management, and behavioral-based safety
8. Third-party management module, including contractor management, supply chain, stakeholder management, complaint management, and permit to work management

Figure C-3. Mitratech CMO Compliance software

EtQ AVIATION SMS

EtQ Aviation Safety Management Software is composed of the following capabilities [33]:

- Incident management, including identification, categorization, investigation, associated risk assessment, and root-cause analysis
- CAPA management to mitigate risk impacts and decrease risk to acceptable levels
- Job safety analysis directly linked to risk assessment to proactively determine preventive measures to mitigate job risk
- Reporting of safety issues and identification of trends across the enterprise
- Audits management linked to risk management to identify areas in which corrective actions are required
- Tracking of key performance indicators
- Operational reporting to determine frequency of events by occurrence type and to record results and effects
- ERM) (see section 8.3) with Bowtie risk modeling
- Risk assessment to determine impacts of safety issues and to measure residual risk once risk has been mitigated

- Failure mode and effects analysis (FMEA)
- Management of environmental objectives and impacts
- Management of change
- Management of compliance with regulations, standards, and requirements
- Management of deviation from operational targets
- Management of controlled documents, such as manuals and SOPs
- Management of emergencies and crises
- Management of employee training
- Management of legislative and regulatory requirements
- Management of quality records, such as inspection results and audit results
- Safety meeting management to foster an enterprise risk culture

Several utilities are available to support the aforementioned modules, namely:

- Risk register and risk assessment (see section 8.3)
- Enterprise configuration center designed to allow administrators to manage users and groups based on their locations and their roles and responsibilities in the enterprise, and to easily and effectively distribute reports across the organization
- Delegation and escalation designed for the assignment of tasks to responsible individuals and for the monitoring of data fields (due dates, review dates) and notifications of escalations to relevant personnel
- Centralized reporting (see section 8.3)

Ideagen Q-Pulse®

The Ideagen SMS solution "Q-Pulse" is designed to monitor quality, safety, risk, and performance throughout the organization [66]. Ideagen Q-Pulse incorporates the following elements, shown in Figure C-4, and some performance monitoring elements:

- Quality and safety assurance:
  - Manage audit lifecycle from planning, scheduling, preparing, reporting, and action tracking through resolution
  - Manage enterprise documents (manuals, forms, SOPs), and make them readily available to relevant parties. This includes change requests, approvals, publishing, change history, drafting, distribution, and document registers
  - Manage corrective and preventive actions (sequencing of activities and tasks through to successful completion), get a holistic assessment of oversight and a detailed visibility of any risk exposure. This includes trending and analysis of risk mitigation strategies, and workflow notifications, reminders, escalations, approvals, due dates, overdue dates, reviews, and closures sent automatically to the right people
  - Manage employee competence and development (demonstrate and maintain staff competency using records of skills, experience, qualifications, training, and cross-referencing with operating procedures)

  - Manage operational quality

- Occurrences reporting:

  - Analyze findings concerning risk assessment, corrective and preventive measures implementation, and incidents mitigation
  - Generate safety reports

- Hazards identification:

  - Investigate and report on incidents and near misses

- Proactive risk management:

  - Avoid or mitigate impact of hazards identified through the hazard identification process (see Ideagen Helicopter Solution in section 8.4)
  - Visually identify gaps
  - Identify effectiveness of controls and barriers
  - Monitor and manage changes
  - Manage responsibilities

- Operational performance management:

  - Collect data from across the organization
  - Organize information into dashboard views
  - Monitor and detect when key performance indicators are approaching or exceeding pre-defined boundaries
  - Analyze trends and emerging risks
  - Manage “out-of-control” actions

- Specialized modules:

  - Manage assets (assign and monitor actions related to assets and equipment; highlight and communicate pending and outstanding actions to relevant people concerning these assets or equipment; record properties of each asset or equipment)
  - Manage customer comments and complaints (collect, organize, view and analyze information; monitor response time to customers’ comments and complaints; spot problems or weak practices within the organization and find solutions)
  - Manage suppliers details (delivery schedule, delays, failures, warranty claims, returns, complaints, audits, and reviews)
  - Identify opportunities for improvement (through data capture, analysis, investigation, and actions development)

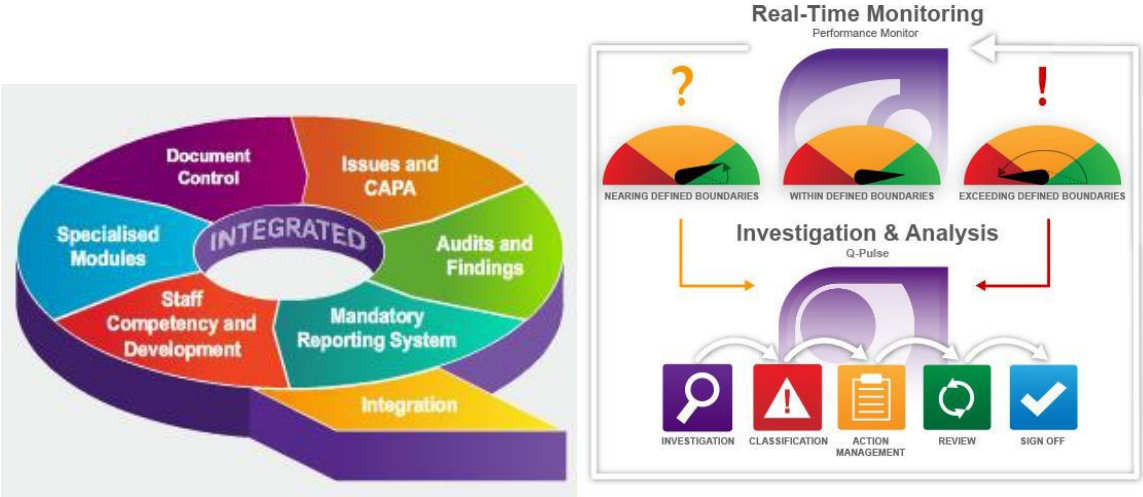


Figure C-4. Q-Pulse modules performance monitoring

Galilot

Galilot SMS is composed of four major components, each consisting of several functions, some of which are shown in Figure C-5: (a) risk assessment; (b) FOD and bird strikes; (c)(d) performance reporting; (e) gap analysis; and (f) safety training and education [47].

1. Policy and objectives:

   – Safety policy
   – Objectives and goals
   – Key safety personnel

2. Safety risk management:

   – System description
   – Hazard identification
   – Risk assessment
   – Mitigation strategies and risk control actions
   – Immediate corrections
   – Voluntary non-punitive reporting
   – Safety event/issue investigation
   – State mandatory reports
   – Bird strike (bird appearance)
   – Foreign object debris (FOD)
   – Runway incursion
   – Accident/serious incident

3. Safety assurance:

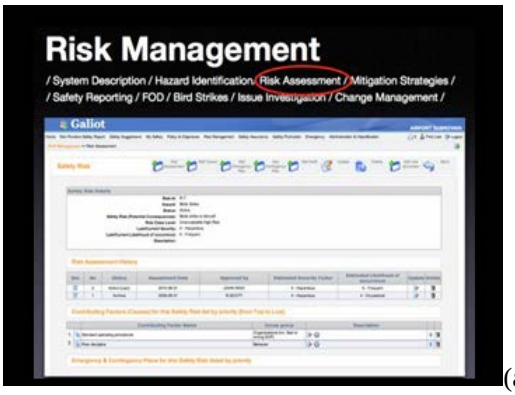
- Gap analysis
- Internal audits
- Management review
- Management of change
- Performance measurement and monitoring

4. Safety promotions:

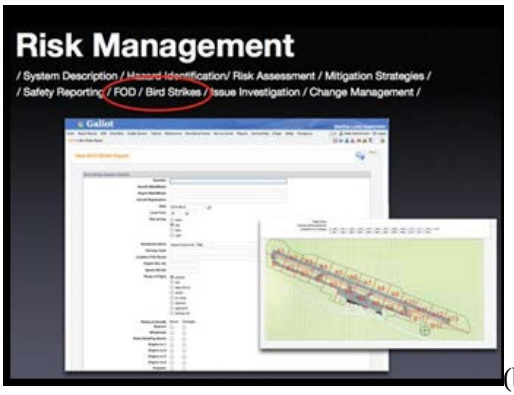
   - Safety training
   - Staff licenses and certificates
   - Safety knowledge database
   - Safety news letter

Galilot SMS is intended to help management make effective decisions; develop a training and education program; involve employees in the management of safety; collect, analyze, and report safety performance data to relevant people; efficiently identify hazards and assess associated risks; evaluate the effectiveness of corrective and preventive actions; promote safety via email and text messages; document meetings, decisions, objectives, and actions; monitor performance of aviation safety systems; investigate and report FOD and bird strikes; and develop a framework for safety accident/incident reporting and investigation.

Galilot SMS is designed to help management answer questions about potential hazards, operational risks, operational safety risk levels, latent conditions or potential accident causes; risks that have no response plan or root cause determined; safety performance levels (according to operations and performance indicators); maturity of their SMS; trends in bird strike, FOD, and runway incursion; quantitative relationships between errors and violations in incidents or accidents; influence of equipment design or condition on safety issues; and influence of the working environment, the organization, or the procedures on safety issues.



(a)



(b)

Figure C-5. Galilot SMS

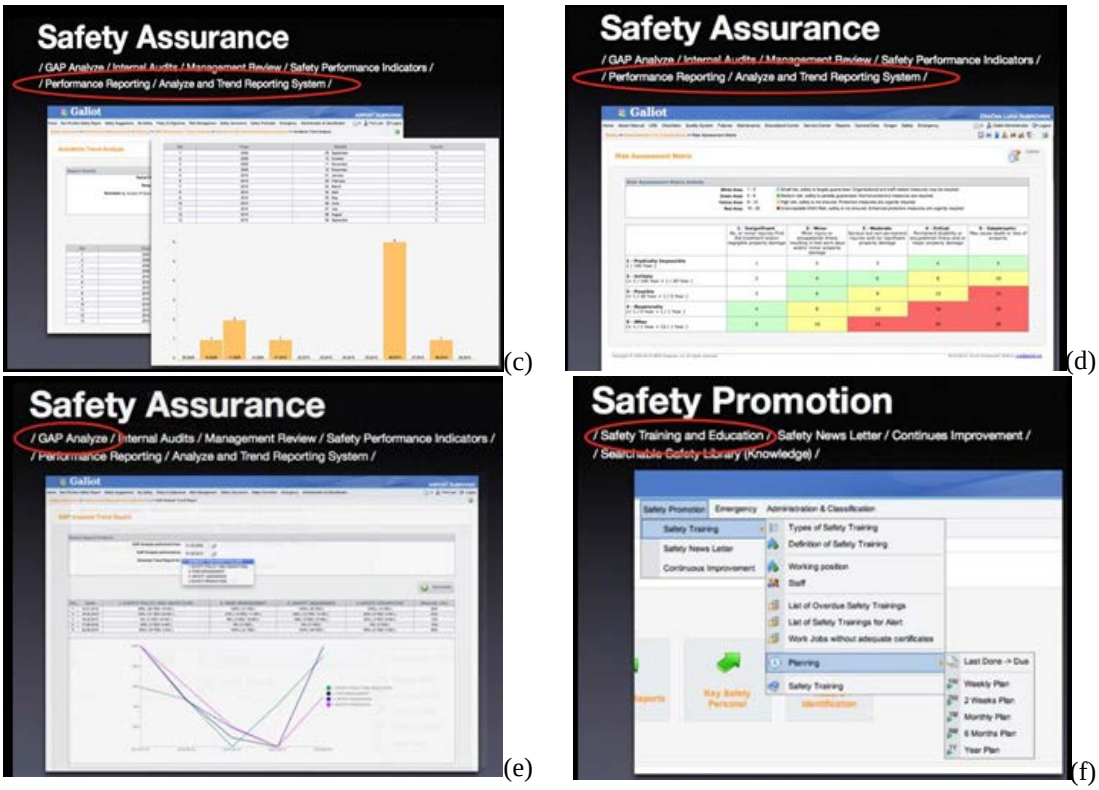


Figure C-5. Galilot SMS (continued)

IndustrySafe

IndustrySafe SMS is composed of several modules that can be organized according to the four safety pillars [58]:

1. Safety policy:

   – Regulation, standard, policy documents

2. Safety assurance:

   – Job safety analysis (track hazards associated with specific jobs or tasks, evaluate resulting risks, and identify mitigation measures and residual risks)
   – Safety inspections (schedule, track, record, and report on compliance rates of on-site safety inspections using pre-defined forms and checklists)
   – Claims (generate various types of claims, such as worker's compensation, property damage, vehicle, and others that can be linked to the same or different incident reports and that can be submitted directly to relevant third parties, such as brokers, insurers, and administrators)

- Industrial hygiene (track and analyze activities, such as quantitative assessments of workers' exposure to potentially harmful substances or events, working area sampling, and personnel monitoring)

3. Risk management (see section 8.5)

   - Hazards
   - Incidents
   - Corrective actions
   - Dashboards

4. Safety promotion

   - Training (track and analyze training activities, required re-certification, regulatory compliance, and training history of each employee based on roles and responsibilities)
   - Behavioral-based safety (conduct observations on employees involved in safety critical tasks to determine whether they execute safe working practices and follow appropriate procedures to minimize injury)
   - Dashboards (see section 8.5)

Figures C-6–C-11 provide snapshots of the various IndustrySafe modules described above.

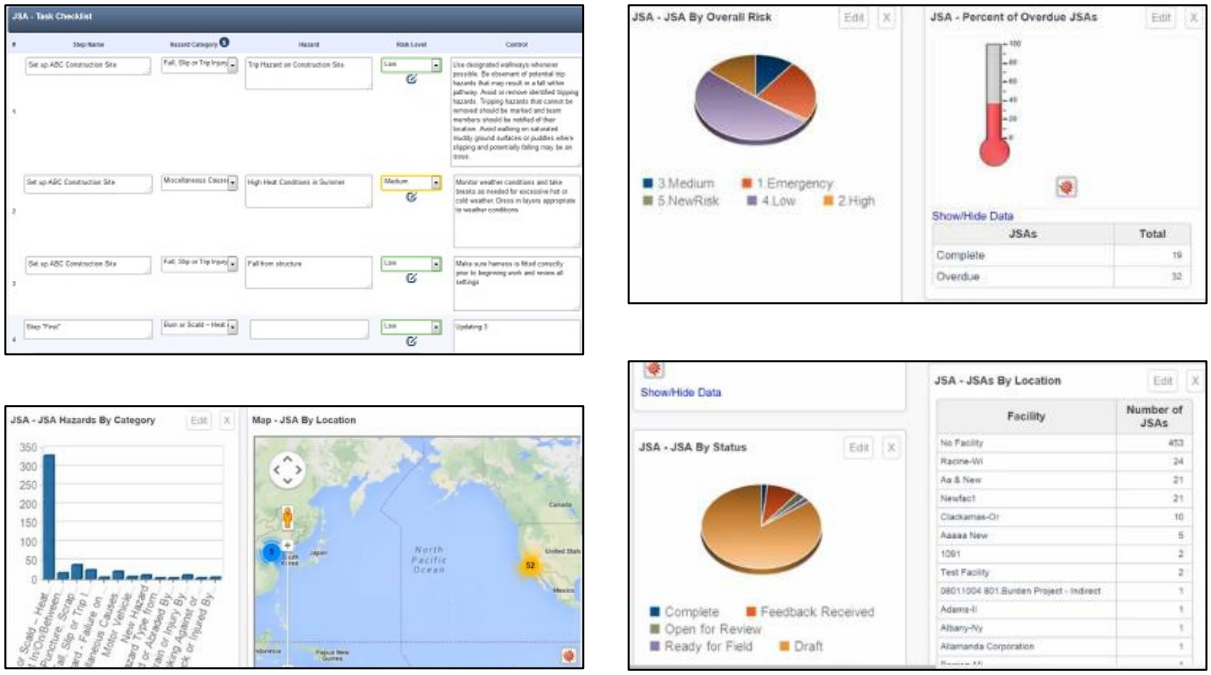


Figure C-6. IndustrySafe job safety module

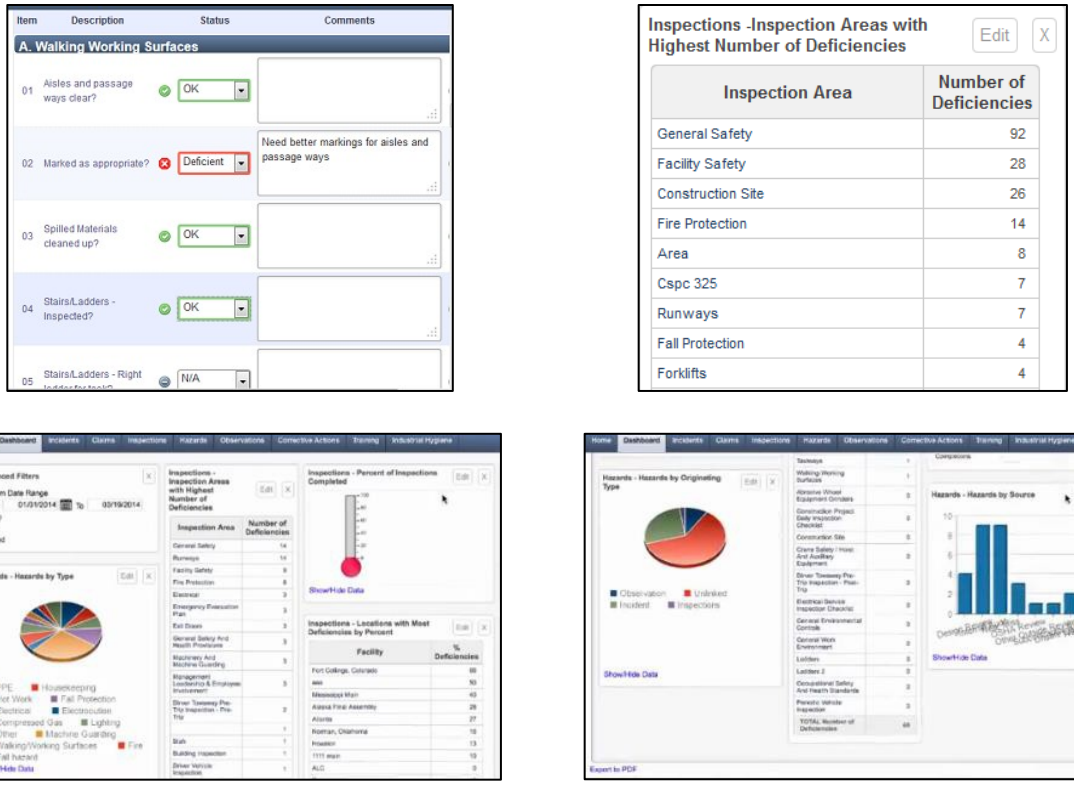


Figure C-7. IndustrySafe safety inspections module

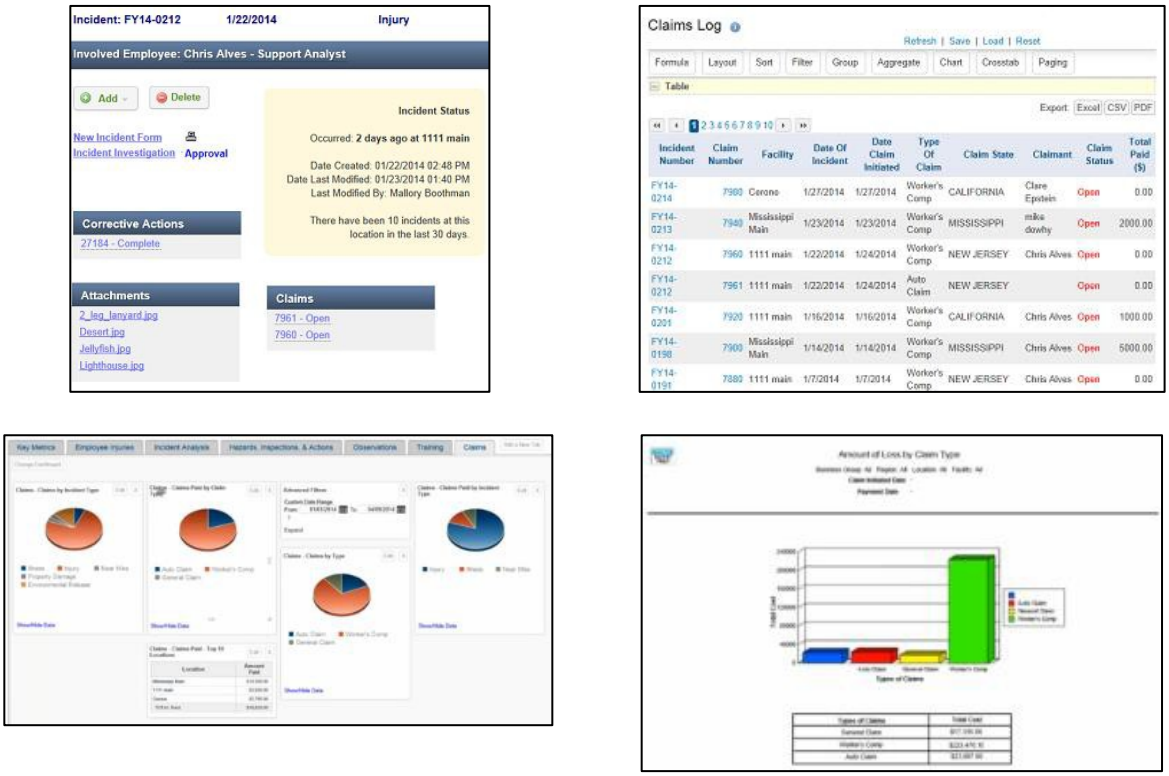


Figure C-8. IndustrySafe claims module

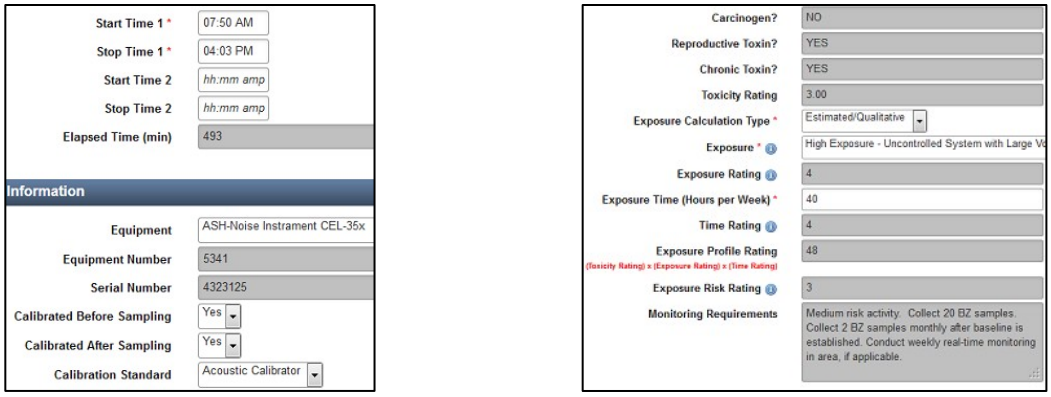


Figure C-9. IndustrySafe industrial hygiene module

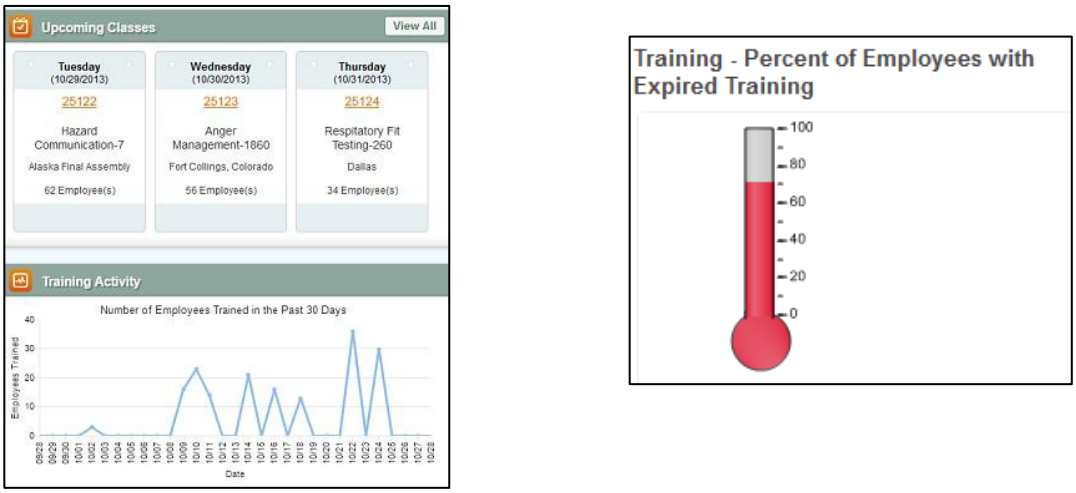


Figure C-10. IndustrySafe training module

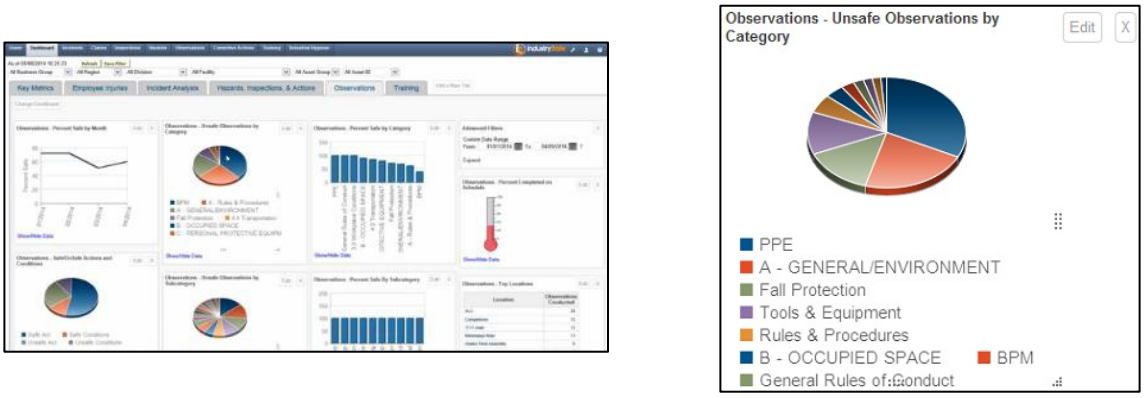


Figure C-11. IndustrySafe behavioral-based module

Intelex

Intelex safety management software for aerospace and aviation [60] is composed of a large number of modules designed for [59]:

1. Safety policy:

   - Document control (access, share, edit, and store relevant organizational documents and critical data in a centralized repository)
   - Safety objectives and policy (identify safety aspects, set safety objectives and targets, and track success of their results; schedule policy reviews, assign policy management to competent individuals, and maintain policy review history and relevant documents and procedures)
   - License management (maintain licenses required by employees or groups of employees, track the critical dates and action items, and ensure that employees are correctly licensed depending on their roles and responsibilities)
   - Legal requirements management (record and track activities, documents, and data associated with regulations, laws, industry codes of practice, permits, and licenses with which the organization must comply)

2. Safety assurance:

   - Job safety analysis (identify and assess hazards associated with specific job tasks, prioritize efforts to reduce risks, define mitigative measures, assign safety-related action items to competent personnel, and analyze results of response to task-related risks over time)
   - Audits and inspections management (manage both internal and external audit and inspection lifecycle from planning, to identification of non-conformance, to implementation of corrective and preventive actions, and to checklists and reports creation)
   - Compliance and legal requirement management (document, assign, and track action items to ensure compliance with relevant legislations; assign responsibilities related to permits, policies, and directives to various employees in the organization; record, track, and report on monitoring activities related to equipment maintenance)

3. Risk management:

   - Enterprise risk register (gain visibility of operational risk at the enterprise level; mitigate most significant enterprise risks and prioritize resources; track and evaluate success of risk management efforts; and perform proactive ERM)
   - Occurrences, incidents, near misses, and dangerous conditions management (record, track, trend, investigate, and report incidents, near misses and safety events; calculate key performance indicators; analyze data and identify dangerous trends)

- Hazard and risk assessments (identify, analyze, score, rank, monitor, review, and mitigate both existing and potential safety risks and hazards throughout the organization)
- Root cause analysis and corrective action management (perform root cause analysis through comprehensive reporting and real-time dashboards and scorecard tools; automate and assign corrective and preventive actions to relevant employees and track completion over time)
- Management of change (track planned changes through checklists, analyses, and approvals to ensure everyone is prepared to implement upcoming operational and organizational changes; standardize approach to change, mitigate risks and hazards associated with change, centralize and streamline change management plan, and create a clear audit trail for planned changes)

4. Safety promotion:

   - Training management (schedule, track, and report on employee training, licensing, qualifications, certifications, and compliance depending on roles and responsibilities)
   - Reporting (report on a variety of safety issues and risks using predefined or custom report formats)
   - Behavior-based safety (identify trends associated with at-risk behaviors; record observations and discussions on job safety measures and compliance; analyze results; and prioritize corrective and preventive actions to ensure job safety)
   - Safety meetings management (schedule, track, and report on safety meetings, manage attendance, spot trends in absenteeism from key meetings, create and assign tasks, and ensure audit preparedness)

Figure C-12 shows some examples of Intelex interfaces for policy details, meeting management, and ERM.

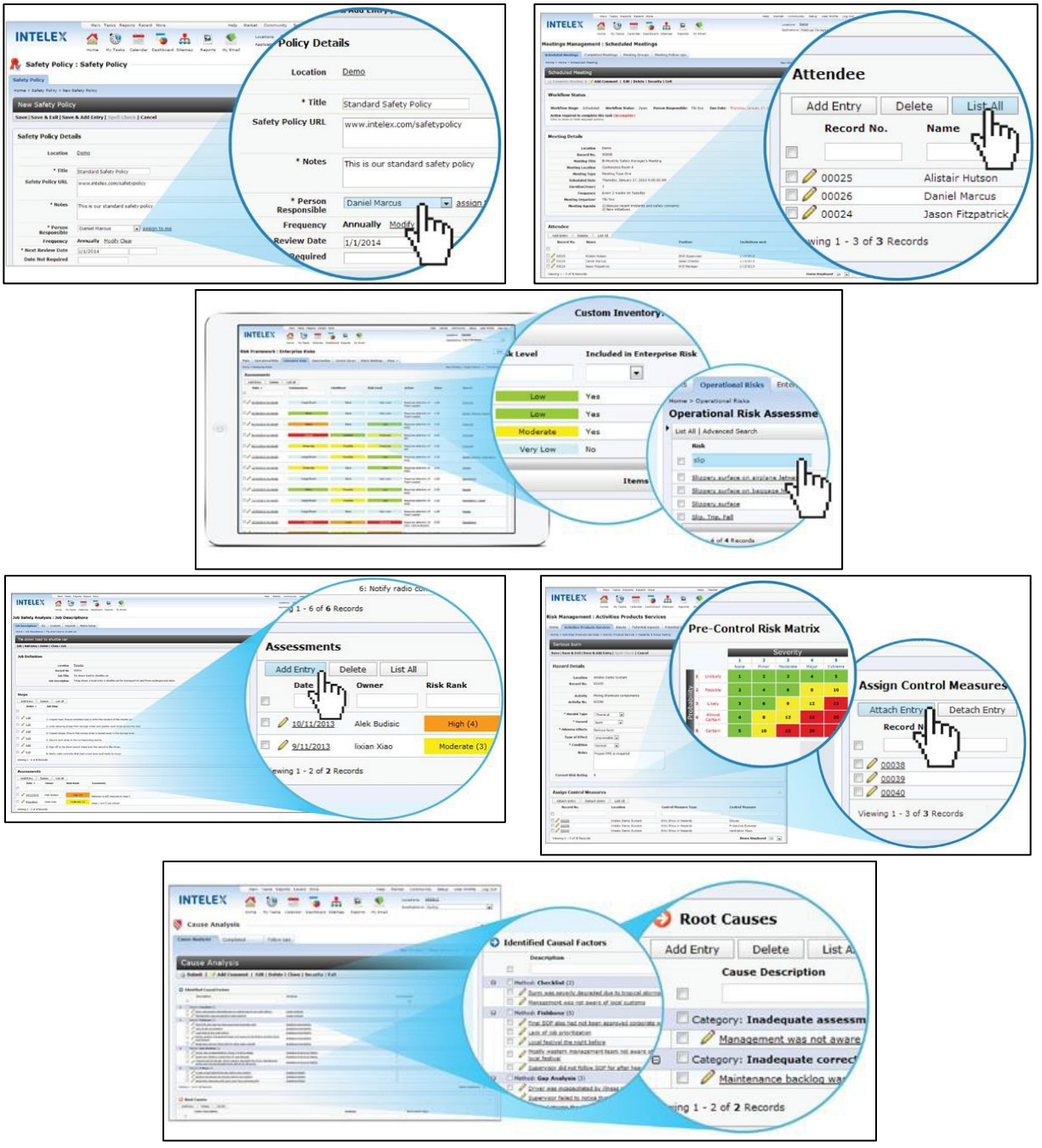


Figure C-12. Intelex safety management software

Q5 SYSTEMS SMS

The Q5 Systems helicopter safety management software [90] is composed of the following modules:

- Document management (upload important documents, procedures, and manuals to a centralized library, and manage permissions and access)

- Audit, inspection, and assessment management (design and conduct audit and inspections according to required internal and external standards; determine and monitor corrective action plans and status; complete or recall audit and inspections; automatically assign tasks to users; and analyze resulting compliance and achievement scores)

- Risk management (see section 8.9)

- Corrective and preventive action monitoring (define corrective and preventive actions from audits, inspections, events, or investigations; initiate corrective and preventive actions plan; assign priority to each action; designate competent personnel to implement corrective and preventive actions plan; perform root cause analysis and cost-benefit analysis; and constantly track status of corrective and preventive actions, such as due dates, escalations, approvals, and closures)

- Investigation management (investigate significant safety events, incidents, minor accidents, and hazards; analyze root causes; define preventive actions; collect and store investigation information; generate investigation reports; generate notifications relating to investigation status and results)

- Hazard and incident monitoring and reporting (capture and report incidents, hazards, accidents, and near-misses using a flexible and customizable tool that collects and strores incident/hazard information across the organization, and monitor associated corrective and preventive actions designed to control associated risks)

- Training tracking management (manage training schedules; assign training manager to oversee personnel training, certificates, qualifications, roles and responsibilities; generate reports to show overdue or upcoming training; and notify personnel of required training action, such as expiring training and new training requirements)

Rivo

Rivo safety management software solution [97] is composed of the following capabilities:

- Safety policy:

  – Document and policy management (store and manage policies and documents such as audit guidelines, operational procedures, training material, and internal and external regulations; perform version control, authorization, publication, and distribution; receive real-time acknowledgement of receipt, modifications, and understanding; maintain audit trail; export policy data to Word, Excel, and PDF)

- Safety assurance:

  - Audit and inspection management (plan, execute, and report on external and internal audits and inspections; identify nonconformance and allocate actions to competent personnel depending on roles and responsibilities; get notified about escalations, nonconformances, and corrective or preventive actions; automate workflows, reviews, and re-audits; get real-time visibility of audit and inspection actions and execution across the organization)

  - Claims and complaint management (handle, investigate, and resolve complaints or claims resulting from safety events, collect relevant information on costs such as claim costs and processing costs, evaluate financial impact of claims and complaints on the organization, attach supporting documents, and link claims and complaints to associated incidents or events)

  - Legal, regulatory, and corporate obligations compliance (manage, enforce, and monitor compliance to relevant laws, regulations, internal policies and procedures across the organization; integrate inspections, audits, corrective or preventive actions, noncompliance reports, and analytics for better control and compliance)

  - Actions and tasks management (see section 8.10)

  - Asset management (manage asset register and associated asset information, such as location, usage, numbers, service history, test results, idle time, damage, and maintenance to anticipate any potential risks)

  - Third-party approval and risk management (identify, assess, and monitor third-party suitability for interaction with the organization, including qualifications and licenses, and approval and renewal processes; record incidents; identify trends; mitigate risk; and record events, actions, and follow-up assessments related to third parties that could impact the organization's safety record at any time)

  - Quality management (capture relevant regulatory and legislative information, support documentation control, carry out inspections and assessments, analyze activity, proactively rectify inefficiencies and nonconformances, manage resulting corrective actions up to completion, produce reports on quality standards compliance, and standardize audit procedures and corrective tasks implementation process across the organization)

- Risk management (see section 8.10):

  - Risk and hazard management
  - Incident reporting and management

- Safety promotion:

  - Surveys and assessments (create surveys and assessments on any safety topic, distribute them to relevant people, set automatic follow-up on actions or issues, and gather information across the organization to ensure compliance with internal

and external measures, efficient use of risk resources, prompt resolution of safety events, and training compliance)

- Business continuity management (communicate procedures and documents with all employees in the organization, ensure everyone complies with the latest processes including employees and third parties, monitor completion of safety-related tasks, analyze business continuity data using analytics, and get notified of potential escalations of safety issues)

- Lessons learned (record and manage results and lessons learned from audits, inspections, assessments, and safety events; and use lessons learned to improve training and quality of operations)

Similarly to Rivo ERM modules, Rivo SMS modules call upon the Rivo Analytics software to perform "big data" operations.

Aviation SMS Pro

The aviation SMS Pro software [111] is composed of several modules addressing the four pillars of safety management:

1. Safety policy:

   - Applicable regulations register
   - Goals and objectives manager
   - Policies and procedures manager
   - Documents manager (with version control and email notifications for modifications, receipts, and reviews)
   - Duties and requirements manager
   - Organizational chart for workflow definition
   - Implementation manager (plan and manage SMS implementation)

2. Safety assurance:

   - Audit suite (identify and manage hazards)
   - Custom inspection form creator
   - Audit manager
   - Audit dashboard
   - Audit scheduler
   - Risk exposure monitor (over time by risk severity)
   - Gap analysis (monitor improvement of compliance and of risk mitigation)
   - Predictive analysis (techniques to analyze current and historical trends to forecast future events)
   - Key performance indicators monitor
   - Performance of SMS monitor

- Safety case manager (identify safety critical aspects, including operational, technical, and managerial)
- Safety training resources manager (manage employee training and qualification requirements)

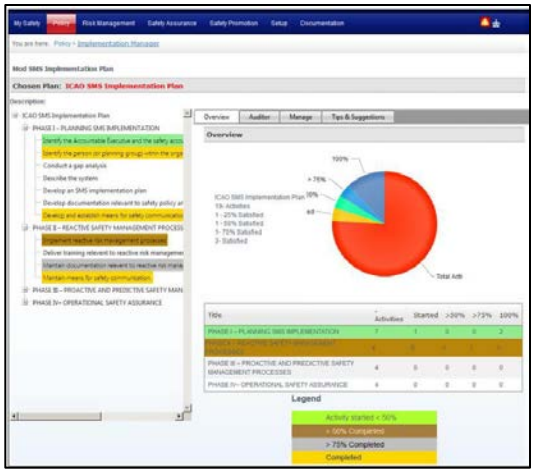
3. Risk management (see section 8.11)

4. Safety promotion:
   - Asset status board (communicate status of equipment)
   - General issue viewer (view desensitized data concerning safety issues)
   - Meeting manager (create and document safety meetings)
   - Safety newsletters (create email-based newsletter to address trending safety management topics)
   - Induction manager (document employee understanding of their SMS roles and responsibilities)
   - All-employee letter (detail SMS implementation to every employee in the organization)
   - Lessons-learned library (search for and review past lessons learned from safety issues)
   - Message board (communicate safety events to all personnel)
   - Safety surveys (receive feedback on SMS effectiveness across the organization)

5. General:

   - Issue reporting (allows every employee to report risks to management)
   - Quick reporting (allows users to submit issues concerning minor safety hazards)
   - Executive dashboard (allows users to review reported issues and to manage their safety tasks)
   - Public reporting (allows third parties to report safety issues or hazards)
   - Flight Risk Assessment Tool (FRAT) (allows managers to control risk based on their assignment to risk assessments)

Figures C-13–C-15 provide some snapshots of activities related to safety policy, safety assurance, and safety promotion.



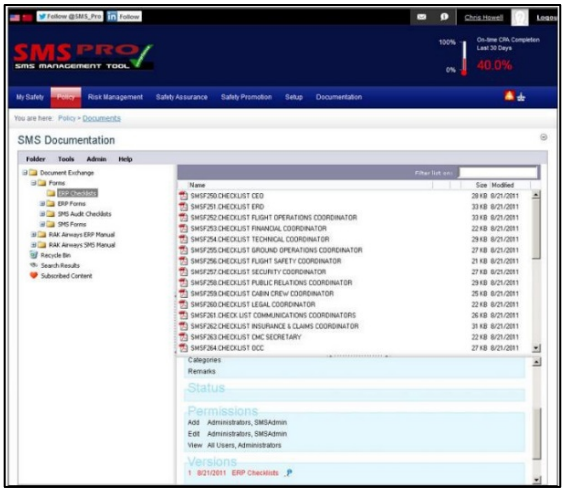
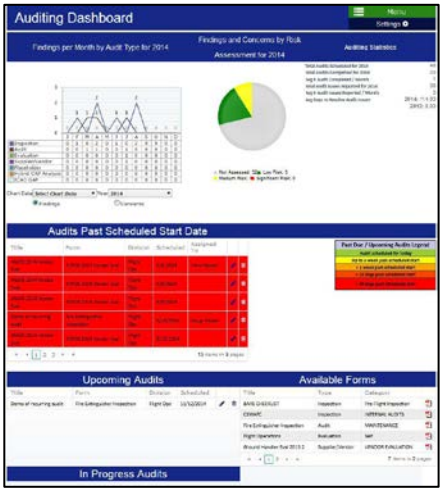
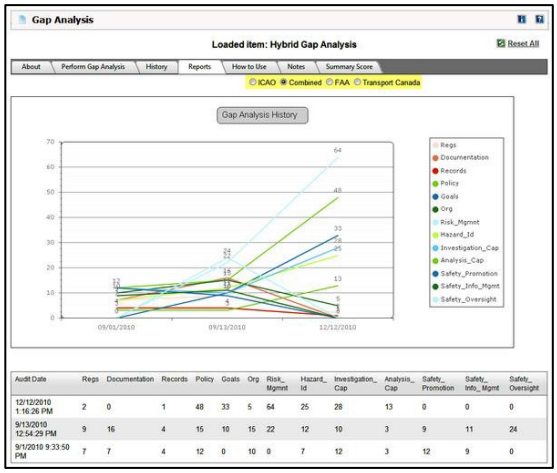


Figure C-13. Aviation SMS pro safety policy module





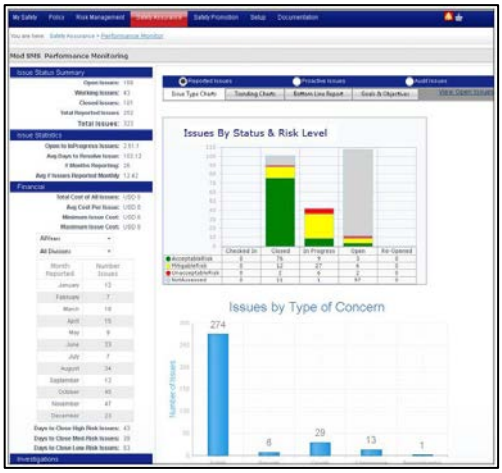


Figure C-14. Aviation SMS pro safety assurance module

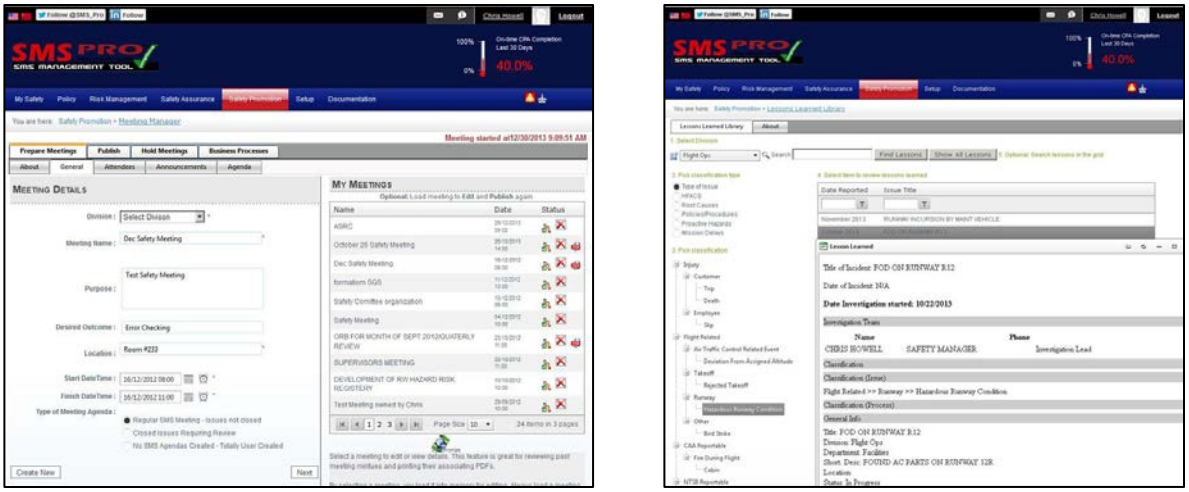


Figure C-15. Aviation SMS pro safety promotion module

Synergi Life

On top of the risk and incident management modules, Synergi Life offers the quality, audit, activity, improvement, and deviation management modules designed to provide a starting solution for an SMS [112].

The audit-management module allows an organization to manage compliance with external requirements and standards, best practices, and internal corporate rules and guidelines through planning, execution, follow-up, and analysis of audits; and through identification, verification, and implementation of action plans and improvement initiatives.

The quality management module allows organizations to identify areas for improvement by looking at nonconformities, deviations, exemptions, complaints, and claims; manage change in external and internal processes, and ensure quality of resulting operations; identify dysfunctional guides and procedures and relevant process changes; secure compliance with relevant standards and legislation; identify, document, and track losses and trends concerning quality; evaluate quality of performance in the organization's processes; evaluate third-party efficiency and quality; evaluate and benchmark other organizations in the same area of operations; secure stable operations and business process integrity; and manage the implementation of new standards, requirements, and laws.

The activity management module allows organizations to manage the overall process of planning, registering for, and following up meetings, initiatives, and other activities.

The improvementmanagement module allows organizations to define target improvement plans and action-implementation strategies; perform systematic improvement studies, including expected gains, due dates, and people responsible to perform safety-related tasks; and collect, process, analyze, and communicate performance data across the enterprise.

The deviation management module allows organizations to coordinate and manage deviations from legal requirements, standard procedures, specifications, regulations, licenses, short- and long-term exemptions, and internal methods and controls to prevent nonconformity. If and when necessary to improve safety, quality or risk level, deviations are documented with proper risk assessment, root cause analysis, mitigation plan, responsible personnel, due dates, and other relevant information.

Universal® Weather & Aviation

Universal Weather & Aviation SMS Manager™ allows organizations to actively manage SMS processes, track safety data, assure and assess safety performance, and store and disseminate safety information throughout flight operations [117]. It was designed to adhere to the four safety pillars:

1. Safety policy to help develop and disseminate safety-management policies, develop and maintain safety management documentation, and define and disseminate accountabilities and responsibilities

    - Policies and processes (draft and post all applicable policies and processes, and define alerts to get notifications when a process is due for review)
    - Applicable manuals
    - Applicable regulations
    - Organizational chart
    - Accountabilities and responsibilities
    - Implementation manager (establish SMS implementation plan)
    - Documents (upload safety documents and manuals, and track versions for documentation control)

2. Safety assurance to assess safety performance and determine the organization's safety health

    - Executive summary
    - Performance monitor
    - Risk exposure
    - Predictive analysis
    - Trending chart
    - Financial chart
    - Custom inspection form
    - Audit scheduler
    - Issue validation
    - Gap analysis (audit SMS against regulatory body standards)
    - Safety survey

3. Risk management to proactively identify hazards and manage the associated risks

- Issue manager (access repository of all reported issues and monitor their risk assessments, classifications, assignments, associated corrective actions, costs, impacts, and their investigations)
- FRAT
- Corrective action manager
- Hazard analysis tool
- Hazard registry (list all identified hazards and associated risks for all employees to see)
- Custom report viewer
- Management of change

4. Safety promotion to disseminate pertinent and critical safety information across flight operations

    - SMS indication manager
    - Newsletter
    - Read file (post safety documents, articles, or links to online documents to disseminate important safety information)
    - Safety bulletin board
    - Message center
    - General issue viewer (disseminate desensitized descriptions of safety issues)
    - Lessons-learned library
    - Meeting manager
    - Qualifications and training manager

All modules use a manager dashboard that provides a snapshot of the organization's SMS performance and its comparison with other organizations' performance. The manager dashboard also shows the organization's safety policy statement, safety goals and objectives, safety workspace to manage and track reported issues, and safety personnel information.

Figure C-16 shows selected Universal Weather & Aviation SMS Manager modules.

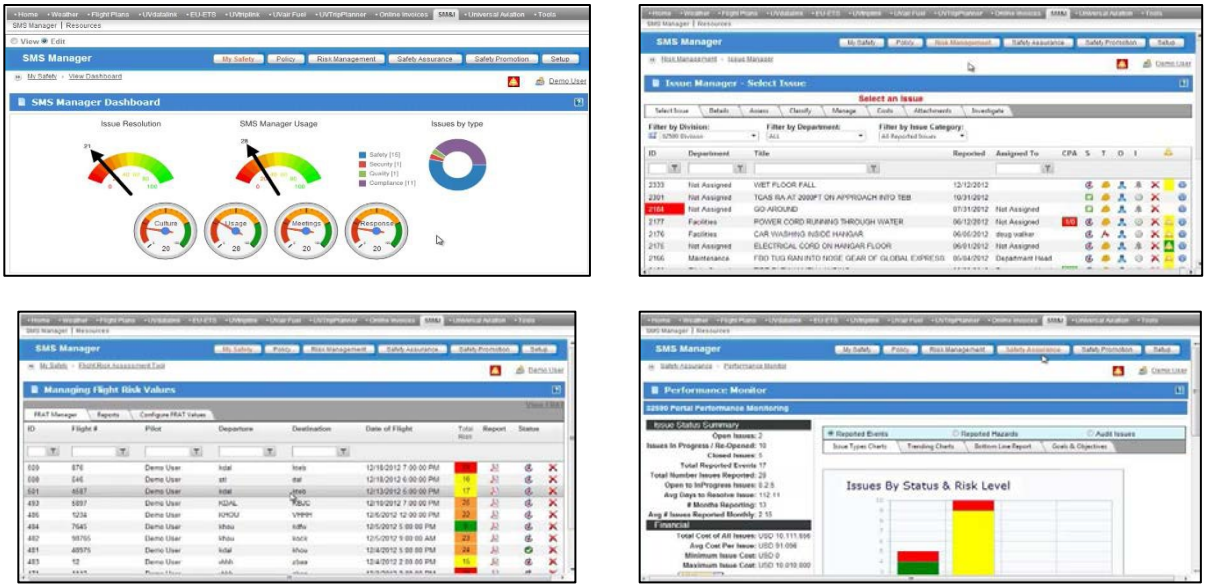


Figure C-16. Universal Weather & Aviation SMS Manager