INTRODUCTION TO SAFETY MANAGEMENT CONCEPTS
WITH FOCUS ON AIRLINE AND AIRPORT OPERATION

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ABSTRACT
The international air transportation industry is strongly affected by an increasing cost pressure. Policies for the aviation production by state regulators are increasingly being replaced by internal company Quality Management Systems (QMS). Safety has to be managed to avoid a leak of safety during this situation. ICAO has created a bottom-up standard for Safety Management Systems (SMS) – ICAO DOC 9859 – applicable for various aviation organisations, including among others airlines and airports. Thereby, those organisations are now responsible by themselves for definition and adherence to an "acceptable level of safety". If an accident occurs, the responsible aviation authority judges this as a lack of the corporate SMS implementation.

The objective of this paper is the introduction of basic concepts in safety management needed for the development of so called Safety Performance Indicators ( SPIs) to get safety assurance in management decisions. Safety policy and targets are the first step of SMS implementation. As a next step safety risk management will indentify hazards and support action planning. This approach ensures that all required safety actions will be identified. Result of this approach is a list of risks and actions, supporting safety performance monitoring. The last step of this approach is the safety promotion concept of training, education and communication for a proactive and generative safety culture.

1. INTRODUCTION
Up to the mid-nineties of the last century safety was improved only by a reactive “fly-crash-fix-fly” approach. The focus of this approach was an intensive accident investigation followed by improving technology, operational procedures and advance training. The objective of the new approach is to avoid human injury, loss of life, and damage to the environment by using proactive Safety Management Systems (SMS) in the aviation industry. In addition to technical improvements the new focus is to contain and mitigate human error and organisational factors through regulation and training (see Figure 1); lessons were learned from incident investigations and other industries such as nuclear energy or space shuttle operation.

Figure 1: The evolution of safety thinking (James Reason; ICAO 2009)

The ICAO determines principles and techniques of international air navigation and promotes the safe and standardised planning and development of international air transport. To achieve the goal of an acceptable level of safety in aviation operation, the
ICAO mandated that its 190 member states have to develop and implement Safety Management Systems. The purpose of the consequent Safety Management Manual (SMM; ICAO DOC 9859) is to support member states in fulfilling the requirements of the ICAO Annexes 6 (Operations), 11 (Air Traffic Services) and 14 (Aerodromes) with respect to the implementation of SMS by operators and service providers.

ICAO's definition of Safety:
“Safety is the state in which the possibility of harm to persons or of property damage is reduced to, and maintained at or below, an acceptable level through a continuing process of hazard identification and safety risk management.” (ICAO 2009, Chapter 2.2.4).

In response to ICAO, the Federal Aviation Administration (FAA) introduced the advisory circular Introduction to Safety Management Systems for Air Operators (AC 120-92) and as well the European Aviation Safety Agency (EASA) provided the Notice of Proposed Amendment (NPA 22-2008) as legal basis. Hence, a SMS has to be implemented at all stakeholders in the Air Transport System (ATS) e.g. upcoming Part-OPS for air operation (old designator was JAR OPS1), to achieve a super ordinate Target Level of Safety (TLS), as defined by Eurocontrol (ESARR4 2001).

2. THE FOUR PILLARS OF THE SAFETY MANAGEMENT CONCEPT
According to ICAO DOC 9859 safety management in the aerospace industry is a combination of the two perspectives traditional and modern. The reactive (traditional) safety management approach which responds to events that already happened (incidents and accidents) is useful when dealing only with technical errors or unusual events. The evolving approach to safety management is following a proactive risk management strategy, identifying hazards before they appear in incidents or accidents and take action to reduce the risks. An additional method for higher safety management level is the predictive method which captures the system performance during operations to identify potential future problems with methods like data mining or modelling (see Figure 2).

![Figure 2: SMS Continuum (adapted from Stolzer 2008)]

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1 see also special EASA regulation Website: [http://easa.europa.eu/flightstandards](http://easa.europa.eu/flightstandards)
As adapted from AC 120-92, SMS is structured upon four basic components of safety management: policy, safety risk management, safety assurance and safety promotion. These four structural elements were titled by the FAA as the “four pillars” of an effective SMS (Stolzer 2008).

2.1. Safety Policy and Safety Culture
A fundamental part of the SMS process is the definition phase. During this phase policies, procedures and organisational structures have to be defined. The safety management concept is using quality management principles (ISO 2007). The requirements on the safety management concept have to be identified. These requirements are influenced by customer requirements and commercial objectives as well as rules and regulations. These requirements must be explicitly referenced into a company policy, and must be fully integrated into the organisation’s mission and vision.

The safety policy is typically written and documented under the authority of the highest level of management of the organisation, approved by the State’s regulator and communicated to all staff of the organisation. The properly communicated safety policy is a prerequisite for the creation and development of positive safety culture inside the aviation organisation.

One of the biggest challenges for an aeronautical organisation is to create and maintain a positive safety culture. Dr. Robert Helmreich, an organisational psychologist, describes three important cultural environments (Helmreich, 1998): national culture encompasses the value system of particular nations, organisational/corporate culture differentiates the behaviour found in various organisations, and professional performance differentiates the behaviour found in different professional groups. Those environments set boundaries for acceptable behaviour and provides a framework for decision making. It is within the intersection of these environments that a safety culture evolves, and it is generated from top down. A positive safety culture as a mixture of these particular cultures and is considered desirable inside an organisation (Figure 3).

![Figure 3: Safety Culture (adapted from ICAO 2009)]
2.2. Safety Risk Management

A risk management system to determine and manage the risks is a fundamental element of a safety management concept. This system shall describe all operational processes and procedures that are accepted, regarding the previously described safety requirements. The operational aviation system consists of organisational structures, processes and procedures, with people, equipment and facilities. System analysis is also the main focus of quality engineering and therefore adapted to SMS. Once the system is well-understood, hazards in the system and environment can be identified, documented and controlled. A hazard is any existing or potential condition that can lead to injury, illness, or death to people; damage to or loss of a system, equipment, or property; or damage to the environment. While identification of every possible hazard would be impractical, aviation service providers are expected to identify all significant hazards directly related to their operations and to get the missing ones from the safety oversight. These top organisations are national or even global in scope like the Commercial Aviation Safety Team (CAST) and its component Joint Implementation Measurement and Data Analysis Team, the Joint Planning and Development Office, and the Distributed National Archive build up in the USA. Europe has a similar programme the European Strategic Safety Initiative (ESSI) with the European Commercial Aviation Safety Team (ECAST). The ECAST team has published guidance material on hazard identification for airline operators. This documentation provides a summary of a number of specific tools and techniques for hazard identification and lists their advantages and disadvantages (ECAST 2009a).

A risk is described as a measure of the expected losses caused by an undesired event and factored with the probability of the event that is occurring (see FAA 2006 and ICAO 2009). As per definition risk is equal to severity multiplied by likelihood. As an example (Stolzer 2008): If a hard landing occurs, the safety office would have a look into the various safety databases of the airline for a forensic approach to risk analysis, and review the reports including “hard landings”. After review, experts would assign a measure of severity to the reports, and then aggregate assignments into an index that describes the severity of the hard landing event. Then an attempt would be made to calculate a statistic rate (the number of hard landings divided by the exposure statistic of the total number of landings in the system), resulting in the likelihood of occurrence index. Using these two indices, a final “risk index” would be obtained by referencing a risk matrix. A simple risk matrix is shown in Figure 4 (FAA, 2006, p. 15).

![Safety Risk Matrix](image)
Most operators are using a management guidance document that describes mitigating action and allowable timelines for corrective and preventive actions, based upon this risk index. This gives the management team the chance to prioritise actions based upon the relative value of the risk indices assigned to each event type. A more sophisticated and proactive method of risk analysis is based on model-building software, which estimates the range of potential severities, possible likelihoods, and measures the effectiveness of those controls. This allows the experts to mitigate hazards that interact with each other and to predict the most probable outcome of events.

According ICAO 2009 SMM, there are many options - formal and less formal - to approach the analytical aspects of risk assessment. For some risks, the number of variables and the availability of both suitable data and mathematical models may lead to credible results with quantitative methods (requiring mathematical analysis of specific data). However, ICAO states that few hazards in aviation lead themselves to credible analysis solely through quantitative methods. Typically, these analyses are supplemented qualitatively through critical and logical analysis of the known facts and their relationships. FAA 2007 suggests that determination of severity should be independent of the probability of occurrence, and vice versa, the probability of occurrence should not be considered when determining severity. Over time, quantitative data may support or alter the determinations of severity and probability, but the initial risk determinations will most likely be qualitative in nature, based on experience and judgment more than on factual data.

Furthermore operations are never fulfilling without residual risk. Therefore the objective of the risk management processes is the development of risk acceptance procedures (see Figure 5). Risk assessment requires that clear lines of responsibility and authority are defined.

![Figure 5: The process of safety risk management (adapted from ICAO 2009)](image)

When the new controls (e.g. additional or revised procedures, changes to training) are implemented, the system is placed in operation and monitored to ensure effectiveness.
2.3. Safety Assurance

Once safety risk management is established, the organisation has to prove that the organisational products/services, arrangements and processes meet or exceed the safety requirements and has also to continue the improvement of their intended safety objectives.

According to ICAO 2009, safety assurance includes the following activities:

- **Safety performance monitoring and measurement** – aircraft operators/service providers shall develop and maintain the means to verify that the safety performance of the organisation complies with the safety policy and objectives, and to validate the effectiveness of safety risk management. This is achieved by monitoring and measuring the outcomes of activities that operational personnel must engage in for the delivery of services by the organisation.

- **Management of change** – the aviation service provider organisation shall develop and maintain a formal process to identify and manage the changes within the organisation which may affect established processes, procedures, products and services. The management of change should ensure that required safety performance is achieved by reducing or eliminating the safety risks resulting from the changes in the organisation, the provision of services or in the operational environment.

- **Continuous improvement of the SMS** – the aviation service provider organisation shall develop and maintain a formal process to identify the causes of sub-standard performance of the SMS, determine the implications of sub-standard performance in operations, and eliminate such causes.

For USA air operation, a significant part of the safety assurance function is assigned to the Internal Evaluation Program (IEP) outlined in the FAA Advisory Circular 120-59.

The European Commission has adopted Regulation No 2096/2005 and laying down common requirements for the provision of air navigation services transposing ESARR3 2000 into Community law. The regulation specifies further the ICAO provisions in relation to ATM and identifies the following safety assurance components:

- **Safety surveys** – shall be carried out as a matter of routine, to recommend improvements where needed, to provide assurance to managers of the safety of activities within their areas and to confirm conformance with applicable parts of their safety management systems;

- **Safety monitoring** - shall ensure that methods are in place to detect changes in systems or operations which may suggest any element is approaching a point at which acceptable standards of safety can no longer be met, and that corrective action is taken;

- **Safety records** - shall be maintained throughout the SMS operation as a basis for providing safety assurance to all associated with, responsible for or dependent upon the services provided, and to the safety regulatory authority. Safety records include all documentation produced and maintained throughout
the operation of the SMS processes, including the risk assessment and mitigation documentation.

Regulators should continuously evaluate the implemented safety management arrangements and processes by aviation service providers by means of external regulatory safety auditing and other safety oversight methodologies.

2.4. Safety Promotion
The aeronautical organisation has to continuously promote safety as a core value with practices that support a positive safety culture. The safety promotion process should be applied at national, regional and global level and includes all efforts to modify structures, environment, attitudes and behaviours aimed at improving safety.

According to ICAO SMS 2009 safety promotion has two elements: safety training and education as well as safety communication. The ESARR3 2000 defines a slightly different scope of safety promotion addressing: safety lesson dissemination and safety improvement.

Safety training and education, as defined by ICAO, should consist of the following:

- a documented process to identify the training requirements;
- a validation process that measures the effectiveness of training;
- initial (general safety) job-specific training;
- initial training incorporating SMS, including Human Factors and organisational factors; and
- recurrent safety training.

The ICAO items are competency related requirements – personnel should be trained and competent to perform their safety management duties and discharge adequately the safety responsibilities arising out of the nature of their job. Properly trained employees have a greater chance of identifying shortcomings and applying effective corrective actions thus achieving better control of risks. The ESARR3 scope is wider – the ATM service providers “shall ensure that staffs are adequately trained, motivated and competent for the job they are required to do, in addition to being properly licensed if so required”.

Safety communication, as defined by ICAO, should aim to:

- ensure that all staff are fully aware of the SMS;
- convey safety-critical information;
- explain why particular actions are taken;
- explain why safety procedures are introduced or changed; and
- convey “nice-to-know” information.

Safety communication is an important enabler for improved safety performance and proactive safety thinking.

Previous to the SMS implementation, most of the aviation organisations worldwide have a Reactive Safety Culture (see Figure 6.). This means safety is seen as a usual business risk and effort is put into accident prevention. Safety is solely defined in terms
of adherence to rules and procedures and engineering controls. Accidents are seen as preventable but managers perceive that the majority of accidents are solely caused by the unsafe behaviour of front-line staff like pilots or air traffic controllers. Senior managers are reactive in their involvement in safety, i.e. they use punishment when accident rates increase and look for fixes to accidents and incidents after they happen.

![Safety Culture maturity levels](adapted from ECAST 2009b)

**Calculative Culture** is the next safety culture maturity level. In this organisation the management will recognise that a wide range of factors causing accidents often originate from their own decisions. A significant proportion of frontline employees are willing to work with the management to improve safety. The majority of staff accepts personal responsibility for their own safety. Safety performance is actively monitored and the data is used effectively. The organisation has systems in place to manage hazards; however, the system is applied mechanically.

In **Proactive Culture** the majority of staff in the organisation is convinced that safety is important from both a moral and economic point of view. Management and frontline staff recognises that a wide array of factors cause accidents and the root causes are likely to come back to management decisions. Frontline staff accepts personal responsibility for their own and others’ safety. The importance of all employees feeling valued and treated fairly is recognised. The organisation puts significant effort into proactive measures to prevent accidents. Safety performance is actively monitored using all data available. Non-work accidents are also monitored and a healthy lifestyle is promoted.

The continually improving **Generative Culture** has had a sustained period (years) without a recordable accident or high potential incident, but there is no feeling of complacency. They act with the awareness that the next accident could be just around the corner. The organisation uses a range of indicators to monitor performance but it is not performance-driven, as it has confidence in its safety processes. The organisation is constantly striving to be better and find better ways of improving hazard control.
mechanisms. All employees share the belief that health and safety is a critical aspect of their job and accept that the prevention of non-work injuries is important. The company invests considerable effort in promoting health and safety at home.

3. SMS IMPLEMENTATION

Annexes 1, 6, 8, 11, 13 and 14 to the ICAO Chicago Convention include requirements for states to establish a State Safety Programme (SSP) aimed to achieve an acceptable level of safety in aviation operations. The objective of these amendments is to harmonise and extend provisions relating to safety management to all categories of aviation service providers.

3.1. Aerodromes

In Annex 14 Volume I Aerodromes Design and Operations, ICAO gives the recommendation on certification of airports for international operations. “States shall establish a safety programme in order to achieve an acceptable level of safety in aerodrome operations.” Guidance is given in the Safety Management Manual (ICAO 2009) and the Manual on Certification of Aerodromes (DOC 9774). SMS implementation is restricted on international airports and instrument flight rules (IFR) in operation. There are no common safety rules on European level, and no community competence; resources and performance depending on individual focus of the aerodrome management and there are different legal transpositions and implementation in the EASA member states. Therefore the upcoming tasks for Aerodromes are safety oversight (competent authorities) and a Certification Specification for aerodrome design (CS-ADR) to be in force 2013.

3.2. Airlines

SMS implementation is defined in Annex 6 Operation of Aircraft - Amendment 30 to Part I (International Commercial Air Transport) and Amendment 11 to Part III (Helicopters) from international side. In European context the Draft NPA-OPS 66A (as already introduced in Chapter 1 of this paper) will bring in force EASA Implementation Rule for Management System (IR MS) in 2010/2012.

![Figure 7: German SMS Implementation Plan (LBA 2008)](image-url)
In Germany the implementation plan has started beginning of 2009 by the Luftfahrt-Bundesamt (LBA), the National Office of Civil Aviation. Four implementation phases are proposed for an SMS State Program by ICAO and transformed into the German national implementation plan (see Figure 7). Each phase is associated with the start of one component of the SMS concept introduced in Chapter 2. First phase objective is the implementation of a safety policy and responsibilities (e.g. safety manager). Second phase objective is risk management for reactive processes, what will be enhanced in phase three to proactive and predictive processes. The last phase objective is a working SMS with safety performance monitoring and safety assurance.

Safety performance indicators (SPIs) or targets (SPTs), that have to be developed in phase three, are the quintessential measures or metrics to reach the acceptable level of safety. They have to be defined in phase four, to reach a working SMS in 2012. As an example for a numeric SPI definition: “No more than 0.8 Cat A and B (most serious) runway incursions per million operations through 2009”. An example for an SPT can be: “By 2010 reduce Cat A and B (most serious) runway incursions to a rate of not more than 0.5 per million operations”. An acceptable level of safety will always be expressed by a number of safety performance indicators and safety performance targets, never by a single one (ICAO 2009). The LBA proposes to define such indicators and targets on a basis of absolute numbers or relative on the basis of the practical operation under valid (prescriptive) rules (EU-OPS, IR OPS, etc.) and the continuous improvement by the SMS itself.

3.3. Air Navigation Service Providers

In order to achieve a uniform European ATM System, all Eurocontrol Member States agreed in 1997 to "implement a mechanism, separate from the service provision, for the multilateral development and harmonization of a safety regulatory regime in the field of air traffic management within a total aviation safety system approach". This mechanism established a Safety Regulation Commission (SRC) as an independent body to the Eurocontrol Agency to set up European Safety Regulatory Requirements (ESARR). The SRC is responsible for the development and uniform implementation of harmonised safety regulatory objectives, the development of target levels of safety and standard of safety performance definition (see also Chapter 1).

Six ESARRs are in force:

- ESARR1: Safety Oversight in ATM.
- ESARR2: Reporting and Assessment of Safety Occurrences in ATM.
- ESARR3: Use of Safety Management System by ATM Service Providers.
- ESARR4: Risk Assessment and Mitigation in ATM.
- ESARR5: ATM Services’ Personnel.
- ESARR6: Software in ATM Systems.

As a regulatory example, the numerical Target Level of Safety (TLS) specified in ESARR4 2001 requires that the probability of ATM directly contributing to an accident (Severity Category 1 event) shall not exceed $1.55 \times 10^{-8}$ per flight hour. The Air navigations Service Providers (ANSPs) are responsible for the implementation of the ATM safety regulatory requirements.
4. STATUS OF SMS IMPLEMENTATION IN BRAZIL
ANAC (AGÊNCIA NACIONAL DE AVIAÇÃO CIVIL - National Civil Aviation Agency) is the Brazilian regulatory agency and was established in March 2006 from the Air Force’s Civil Aviation Department (DAC), the former civil aviation authority. ANAC is in charge of setting rules and performing activities related to air transport and civil airport infrastructure safety, except for those related to airspace control systems and investigation and prevention of aeronautical accidents, which are under the responsibility of the Aeronautics Command from the Ministry of Defence (notably DECEA for Air Traffic and Space Control and CENIPA the Accident and Incident Investigation and Prevention Board).

Brazil has already introduced a SSP for Civil Aviation Operational Safety (PSO-BR) to achieve an acceptable level of safety in aviation operations (ICAO 2009): “The PSO-BR adopts as assessment indicator the division of annual number of aeronautical accidents involving passengers’ killing in regular operations by each hundred thousand taking off operations” (from ANAC 2008).

ANAC and the Aeronautical Command Authorities establish their own specific safety program in line with the Brazilian commitments in international agreements. The implementation plan consists of four steps, where step one is already fulfilled with gap analysis and modification of the national regulations for airport SMS (RBAC 139). The seven main international airports of Brazil were granted temporary certificates. The final operational certification processes, guidance and promotion material are underway.

5. OUTLOOK
The aviation system involves a complex interaction between different technical and human centred sub-systems operated by a wide range of different stakeholders (airlines, airports, air navigation service provider and maintenance repair and overhaul etc.). Each organisation must manage the hazards that fall under their managerial control, but should also co-operate with other stakeholders to help manage interactions and interfaces. In this complex hierarchy of different systems, a safety outcome in one system could cause hazards in another system. Therefore States have a responsibility, under the Chicago Convention, to ensure that acceptable levels of safety are established and maintained. States are further required to ensuring that SMS are implemented by all providers of the Air Transport System, which include the monitoring of overall safety levels. A holistic approach to performance monitoring is an essential input to safety management decision-making. It is important to ensure that good safety performance is attributable to good performance of the safety system, not simply to lack of incidents. An approach to worldwide safety monitoring and data collection supports the development of safety indicators at national, regional and perhaps at global level.

The Safety Department of Deutsche Lufthansa AG flight operations, has recently started a research project (SAMSYS 2010) to collect hazards from various sources and have a quantitative assessment of the appropriate risk defensive measures in airline operations. Hazards may be identified through a data-driven (quantitative) methodology or qualitative process (discussions, interviews and brainstorming). In a data-driven approach, hazards are identified and recorded through a systematic process which allows for traceability and further analysis (Stolzer 2008). There are various types of recorded observations which may be used to identify hazards. Sources for hazards identification can be Flight Operation Data Analysis (FODA), company audits, staff
surveys, hazard reports and others. Investigation and reports of past occurrences may provide rich material as to existing hazards as well as, alternative to these, hazards which may arise. For example, an occurrence report may identify the hazard of standing water affecting the integrity of landing aid equipment at an airport, but through this report other hazards which may affect this equipment may also be identified. Furthermore, real-time and non real-time simulations may be used to identify likely hazards and their interactions (FAA-EUROCONTROL 2007). Using simulation modelling it may be easier to identify potential hazards and their potential outcomes. For this purpose, in addition to theoretical considerations also practical experiments using a full flight simulator are required and planned by the project group.

Planned outcome from the data driven approach is one combined SPI or a set of SPIs. They will be used for safety assurance in management decisions and also implemented into the incentive system of the airline/airport management system.

REFERENCES