Safety Management-Aerodrome

Module 4: Safety Performance Monitoring
INTRODUCTION
  Background
  SMS framework

SAFETY PERFORMANCE INDICATORS
  SELECTION

RISK ASSESSMENT
  AGGREGATED RISK
  SIRA

TREND ANALYSIS
  AGGREGATED RISK
  SAFETY TARGETS

CONCLUSIONS
SMS Framework

STATE SAFETY PROGRAMME (SSP) FRAMEWORK

SAFETY POLICY, OBJECTIVES & RESOURCES
- Primary Aviation Legislation (incl. CE-1)
- Specific Operating Regulation (incl. CE-2)
- State System and Functions (incl. CE-3)
- Qualified Technical Personnel (CE-4)
- Technical Guidance, Tools and Provision of Safety Critical Information (CE-5)

SAFETY RISK MANAGEMENT
- Licensing, Certification, Authorization and Approval Obligations (CE-6)
- Safety Management System Obligations
- Accident and Incident Investigation
- Hazard Identification and Safety Risk Assessment
- Management of Safety Risks (Including CE-8)

SAFETY ASSURANCE
- Surveillance Obligations (incl. CE 7)
- State Safety Performance

SAFETY PROMOTION
- Internal, Communication and Dissemination of Safety Information
- External, Communication and Dissemination of Safety Information

The State has established the acceptable level of safety performance (ALoSP) to be achieved through its SSP by means of safety performance indicators and targets.
SMS Framework

- Safety assurance is based on the application of the principles of quality management to the control and mitigation of hazards that threaten the operation of a system.

- Service providers need to monitor operations continuously to detect:
  - Changes that may occur in the operation with the potential to introduce new hazards or adverse consequences;
  - Deterioration in operating procedures, facilities, equipment conditions or human performance, that could reduce the effectiveness of controls and mitigations.
Enablers for Performance Based System (PBS)
Safety Performance: Safety achievement as defined by the safety performance targets and indicators.


Safety Performance Target: Planned or intended objective for safety performance indicator over given period.
Safety Performance Indicators

Indicators provide meaningful information about the behavior of a system

What are safety performance indicators for:

- Provide an objective safety measurement
- Essential for comparison with safety targets (ALOSP)
- Measure the effect of implemented mitigating actions

Concepts:
- OCCURRENCE UNITS
  - BY CATEGORY
  - BY SEVERITY
  - BY PHASE
  - BY EVENT TYPE

- EXPOSURE UNITS
  - YEARS
  - MONTHS
  - NUMBER OF OPERATIONS
  - NUMBER OF FLIGHTS
  - FLIGHT HOURS
  - PAX/KM
CHARACTERISTICS

- **OBJECTIVE, QUANTIFIABLE & MEASURABLE**
  - careful definition of the indicator
  - unambiguous to avoid occurrence interpretation and counting
  - permitting statistical inferential procedures

- **VALID OR REPRESENTATIVE TO WHAT IS TO BE MEASURED**
  - association between indicator and occurrence does not necessarily mean that the indicator and event are causally related

- **MINIMUM VARIABILITY WHEN MEASURING THE SAME CONDITIONS**
  - measuring should read the same value under equal conditions

- **SENSITIVE TO CHANGE IN ENVIRONMENTAL OR BEHAVIORAL CONDITIONS**
  - capability to detect trend changes

- **COST OF OBTAINMENT IS CONSISTENT WITH THE BENEFITS**
  - costs for obtaining and using the indicators should be acceptably low

- **COMPREHENDED BY THE USERS**
  - different indicators for managers and safety analysts

- **SET OF INDICATORS SHOULD REMAIN MANAGEABLE**
  - the set of indicators should not contain too many, rendering the management impracticable
**Lagging Vs leading indicators**

**Leading SPIs** measure processes and inputs being implemented to improve or maintain safety. Also known “activity or process SPIs” as they monitor and measure conditions that have the potential to become or contribute to a specific outcome.

**Lagging SPIs** measure events that have already occurred. They are also referred to as “outcome-based SPIs” and are normally the negative outcomes the organization is aiming to avoid.
Lagging Vs leading indicators concept phases

Precursor event
- Birds activity
- Birds radar detections

Leading indicator
- Bird Scaring activities
- Crops C control
- Grass mowing

Lagging indicator
- Bird- engines ingestions= LOC-I
- Bird strikes
Lagging indicators

Event types:
LOC-I, CFIT, RE, MAC, RI

Causal Factors/Precursors:
GPWS alerts/TCASRA/unstabilized approach
Lagging SPIs are divided into two types:

- **Low probability/high severity**: outcomes such as accidents or serious incidents.

- **High probability/low severity**: outcomes that did not necessarily manifest themselves in a serious incident or accident, these are sometimes also referred to as *precursor indicators*. SPIs for high probability/low severity outcomes are primarily used to monitor specific safety issues and measure the effectiveness of existing safety risk mitigations.
Examples of links between lagging and leading indicators

Combined leading and lagging indicators provide a more comprehensive and realistic picture of the organization’s safety performance.
Defining SPIs: Each SPI should include

- a description of what the SPI measures

- the purpose of the SPI (what it is intended to manage and who it is intended to inform);

- the units of measurement and any requirements for its calculation;

- who is responsible for collecting, validating, monitoring, reporting and acting on the SPI

- where or how the data should be collected; and

- the frequency of reporting, collecting, monitoring and analysis of the SPI data
SPI Classification

Safety Performance Indicators

**Tier 1**
Integrated Civil Aviation System

**Tier 2**
Service Providers Performance

**Tier 3**
Safety Risk Management Activities

Adverse Outcome:
Accidents and Serious Incidents

Precursors:
Occurrence types related to contributing and causal factors

Safety Actions:
Recommendations, mitigations, initiatives, priorities, etc.
## SPI Classification

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<th>LEVEL</th>
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<tbody>
<tr>
<td>TIER 1</td>
<td><strong>SPI 1</strong> LARGE COMMERCIAL TRANSPORT AIRCRAFT ACCIDENTS / 10^6 FLIGHTS</td>
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<tr>
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<td><strong>SPI 2</strong> LARGE COMMERCIAL HELICOPTER ACCIDENTS / 10^6 FLIGHTS</td>
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<td><strong>SPI 5</strong> GENERAL AVIATION ACCIDENTS / 10^6 FLIGHTS</td>
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<td>TIER 2</td>
<td><strong>LOC-I</strong> STICK SHAKER / INCREASED ROLL ATTITUDE OR RATE / HIGH PITCH ANGLE / OVERSPEED (VERTICAL OR CONFIGURATION) / FAILURE OF PRIMARY FLIGHT INSTRUMENTS (RATES)</td>
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<td><strong>CFIT</strong> EGPWS HARD WARNINGS / DESCENT BELOW MSA / NAVIGATION ERRORS (RATES)</td>
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<td><strong>RE</strong> ABNORMAL RUNWAY CONTACT / LOSS OF CONTROL ON GROUND / LONG OR FAST LANDINGS / OCCURRENCES WITH CROSSWIND CONDITIONS / HIGH SPEED REJECTED TAKE-OFFS / ATA32 OCCURRENCES</td>
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<td><strong>MAC</strong> LOSSES OF SEPARATION / INADEQUATE SEPARATION / LEVEL BUSTS / AIRSPACE INFRINGEMENT (RATES)</td>
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<td></td>
<td><strong>RI-VAP</strong> RUNWAY INCLUSIONS (RATES)</td>
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<td><strong>G-COL</strong> TAXIWAY INCURSIONS / AVOIDING MANEUVERS DURING TAXI / AIRCRAFT COLLISIONS AND COLLISIONS WITH AIRCRAFT (RATES)</td>
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<td><strong>SC-F</strong> ENGINE FAILURE / FLIGHT CONTROL PROBLEMS / HELICOPTER TAIL ROTOR AND MAIN ROTOR BLADE FAILURES OR MALFUNCTIONS (RATES)</td>
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<td>TIER 3</td>
<td><strong>SPI 6</strong> NUMBER OF COURSES / SAFETY COMMUNICATIONS / WORKSHOPS TO AWARE ABOUT SPECIFIC SAFETY ISSUES</td>
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<tr>
<td></td>
<td><strong>SPI 7</strong> % OF THE OPERATIONAL STAFF TRAINED IN ACCORDANCE WITH UPDATED SOPs</td>
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Selection Process

1. INDICATOR IDENTIFICATION
   - Goals
   - Selection Criteria
     - Scope
     - Reliability
     - Availability

2. CALCULATION & DISPLAY
   - Statistic Process Control
     - Sample Size
     - Graphs
     - Metrics

3. ANALYSIS RESULTS
   - Monitoring
     - Alert Thresholds
     - Update Interval
     - Interpretation

4. VALIDATION
   - Do results fulfil the goal as expected?
     - Objective, Quantifiable & Measurable
     - Valid or representative to what is to be measured
     - Sensitivity to changes
     - Cost of obtaining vs Benefits
     - Understanding & Intuitivity

SUITABLE INDICATOR

SORRY TRY AGAIN!!

NO

YES
Contamination of Airframe surface On ground

Inadequate GS De/anti-icing

Contamination of engine intake on ground

Ground staff de/anti-icing

Training

Crew perform AFM procedures for engines ice

AC TO with Contaminated Surfaces or engines

Ground handling Cold weather Ops CAT Airplane

Inflight structural failure resulting in Fatalities

RESA SOP

RTO

Collision with Structure resulting in injury

LOC-I

I1

I2

I3

I4

I5

I6
Term used in economics to measure the vulnerability of a system to catastrophic failures caused by events or conditions in intermediate stages.

This concept can be easily extrapolated to aviation as a high level indication of the exposure of the aviation system to accidents, and used to monitor the safety performance with respect to safety targets.
Concept

- It can be used as a high-level SPI to measure safety performance.
- Aggregated risk can be calculated as the product of the different combination of factors of a bowtie diagram (safety events, prevention & recovery controls).
Safety Issues Risk Assessment (SIRA)

Best practice developed in the framework of ARMS, as the product of four factors (prevention, avoidance, recovery and minimization of losses) instead of the old severity x likelihood formula. This new framework includes the risk controls (barriers) in the risk assessment.

Risk Estimation based on:

- Probability/frequency of triggering event
- Effectiveness of avoidance barriers
- Effectiveness of recovery barriers
- Severity of the most probable accident outcome
ARMS in a Nutshell

**Event Risk Classification**

*First step for all incoming data*

**HOW TO DO IT:**

- **Event**: The occurrence of the consequences of the remaining barriers between this event and the accident scenario identified in Question 1.
- **Consequences**: The probability and severity of the consequences of the remaining barriers.
- **Risk Level**: High, Medium, Low.
- **Risk Index Number**: Used in database analysis (trending & statistics).

**RESULT:**
- Immediate action & further investigation required
- More refined Risk Assessment and/or investigation required
- No action required. Contributes to the Safety Database.

**Examples only.** To be customized at each organization.

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**Safety event/data** START HERE

**Investigations**

**Safety Issue**

**Database**

**Data Analysis**

**Actions to reduce risk**

**Register**

**Safety Performance Monitoring**

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**Safety Analysis**

START HERE

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**Quick Reference Guide**

**SIRA**

**Safety Issue Risk Assessment**

**HOW TO DO IT:**

1. Define the Safety Issue precisely:
   - Scope the issue in terms of hazards, locations, etc.
   - See section 4.2 for detail.
2. Develop the related potential accident scenarios:
   - There may be several accident scenarios within one Safety Issue.
   - Select the most critical scenarios (one or more) for the risk assessment.

**Fixed for:**
- Safety issues
- Safety Assessments, when quantifiable
  (Management of Change process)

**Frequency**

1. **Effectiveness of triggering event**
   - **Avoidance**
   - **Reduction**
   - **Mitigation**

2. **Effectiveness of avoidance barriers**
   - **Avoidance**
   - **Reduction**
   - **Mitigation**

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**RESULT:**
- **Stop**: Discontinue the concerned part of the operation until acceptable risk level.
- **Improve**: Still unacceptable risk but tolerable for a short time. Action required.
- **Sacrifice**: Frequent monitoring required, as this is at the limit of acceptable.
- **Monitor**: No action through the routine database analysis.
- **Acceptable**: No specific action required.
SIRA/ARMS Steps

1. **Define the Safety Issue Precisely**
   - **Safety Issue**: A manifestation of a hazard or combination of several hazards in a specific context
   - **Scope the Issue in Terms of Hazards, Locations, A/C Types, etc.**

2. **Develop the Related Potential Accident Scenarios**
   - **There May Be Several Accident Scenarios Within One Safety Issue**
   - **Select the Most Critical Scenarios (One or More) for the Risk Assessment**

3. **Analyze (Each) Scenario Using the SIRA Model**
   - **Identify the Accident Outcome of the Scenario**
   - **Identify What is Considered the Triggering Event**
   - **Decide What You Consider as the Undesired Operational State (UOS)**
   - **List the Avoidance and Recovery Barriers and Review Their Robustness**

4. **Run the SIRA with Numbers**
   - **Consider Using the SIRA Excel Tool**
   - **Select a Known or an Estimated Value for Each of the 4 SIRA Components**
<table>
<thead>
<tr>
<th>Estimated Frequency of the Initial Event (per Flight Sectors) is:</th>
<th>The Barriers Will Fail In Avoiding the UE...</th>
<th>The Barriers Will Fail In Recovering the Situation Before the Accident...</th>
<th>The Accident Severity Would Be...</th>
<th>Tolerability Limit</th>
<th>Short Definition</th>
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<td>Virtually Every Flight</td>
<td>Practically Always</td>
<td>Practically Always</td>
<td>Catastrophic</td>
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<td>3 fatalities or more</td>
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<td>Once Every 10 Times</td>
<td>Major</td>
<td>1E-07</td>
<td>Serious injuries</td>
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<td>In 100 Times</td>
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SAFETY ANALYSIS TECHNIQUES

Trend Analysis

- Preliminary assessment using expert judgment
- Event coding and
- Risk allocation (ARMS-ERC)

Internal Investigations
- Collection and assessment of information
- Identification of causes and contributing factors
- Risk allocation (ARMS-SIRA)
- Safety recommendations

Trend Analysis
- Identification of Safety Performance Indicators (SPI)
- Statistical analysis of SPI time series
Setting targets with SMART safety objectives

- Safety objectives can be difficult to communicate and may seem challenging to achieve; by breaking them down into smaller concrete safety targets, the process of delivering them is easier to manage.

- Organizations should identify the key areas that drive the safety performance and establish a way to measure them.

- Once an organization has an idea what their current level of performance is by establishing the baseline safety performance, they can start setting SPTs to give everyone in the State a clear sense of what they should be aiming to achieve.

- The organization may also use benchmarking to support setting performance targets.
Example SPTs with SMART safety objectives

Objective 1
50% reduction in runway excursions by 2022

Number of runway excursions

Target 1a
Target 1b
Target 1c

Time

2018 2019 2020 2021 2022

(100 / million movement)
Objective 1
50% reduction in runway excursions by 2022

Number of runway excursions

(100 / million movement)

Target 1a achieved

Target 1b not achieved

Target 1c
Applicable Techniques

**Trend analysis:**
- By monitoring trends in safety data, predictions may be made about future events. Trends may be indicative of emerging hazards.

**Statistical analysis:**
- This method can be used to assess the significance of perceived safety trends often depicted in graphical presentations of analysis results. While statistical analysis may yield powerful information regarding the significance of certain trends, data quality and analytical methods must be carefully considered to avoid reaching erroneous conclusions.
## Time Series

### Aircraft Handling Related Reported Occurrences

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<tr>
<th>YEAR</th>
<th>MONTH</th>
<th>OCCURRENCE</th>
<th>EXPOSURE</th>
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Example of representation of safety triggers (alert) levels

Alert Levels
Mitigating actions may need to be taken when trend goes beyond +1 or +2 standard deviations from the mean of the preceding period

Beyond +2 standard deviations
+2 standard deviations
+1 standard deviation
Mean of preceding period

Target Level
Aim to maintain the trend below the target line
Two SPI Performance Markers

- Establish high occurrence rate Alert trigger within each SPI
- Establish planned improvement Target level within each SPI

"what gets measured gets noticed."
Alert Trigger setting

- Statistical Alarm bell (out of control criteria)
- Based on **SPI’s preceding period’s data performance** i.e Average & Standard Deviation values
- Ave+1SD; Ave+2SD; Ave+3SD
- Continuous monitoring for abnormal trends
Alert Trigger setting – 3 criteria

One single point above 3- SD line

Two or more consecutive points above 2- SD line

Three or more consecutive points above 1- SD line
Target Level setting

- A planned (desired) occurrence rate improvement for a new monitoring period
- Reduction (e.g. 5%) of current period’s Average over preceding period’s Average rate
- Target achievement assessed at end of each monitoring period
### Example

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<thead>
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<th>Month</th>
<th>OCC</th>
<th>FH</th>
<th>Rates*</th>
<th>AVG</th>
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<th>AVG+2SD</th>
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**AVG** = 9.11
**SD** = 2.66

**AVG+1SD, AVG+2SD, AVG+3SD**

Current year alert level setting criteria is:
Preceding year AVG+1/2/3/SD

Current year target is say 5% Ave rate improvement over the AVG rate for the preceding year which is 8.66

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**Example Graphics**

### Preceding Year-2015

![Graph showing Preceding Year-2015 rates and AVG](image)

### Current Year-2016

![Graph showing Current Year-2016 rates and AVG](image)
At end of a monitoring period –

- Each *SPI’s performance* is manifested by its own Alert & Target achievement outcome as follows:

**Alert Level not breached – Yes / No**

**Target achieved – Yes / No**
CONCLUSIONS

• A safety performance based system is built upon:
  – SMS/SSP
  – agreement and selection on indicators
  – 3 tiers indicators supported by a hazard analysis method (e.g: Bow tie)
• Trade-off for the selection of indicators: start from a simple scheme and grow as your needs evolve
• Aggregate risk as a global SPI through:
  – SIRA
• Methods for safety monitoring:
  – trend analysis
  – alert levels
• Safety performance monitoring:
THANK YOU!