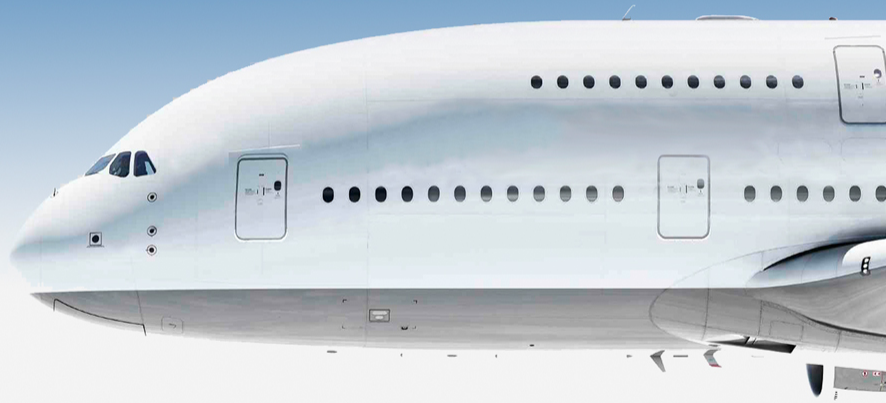
ICAO UNITING AVIATION

SAFETY MANAGEMENT SYSTEM



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SMS Aerodrome Worshop

Nov 2018, Cairo

Safety Management-Aerodrome

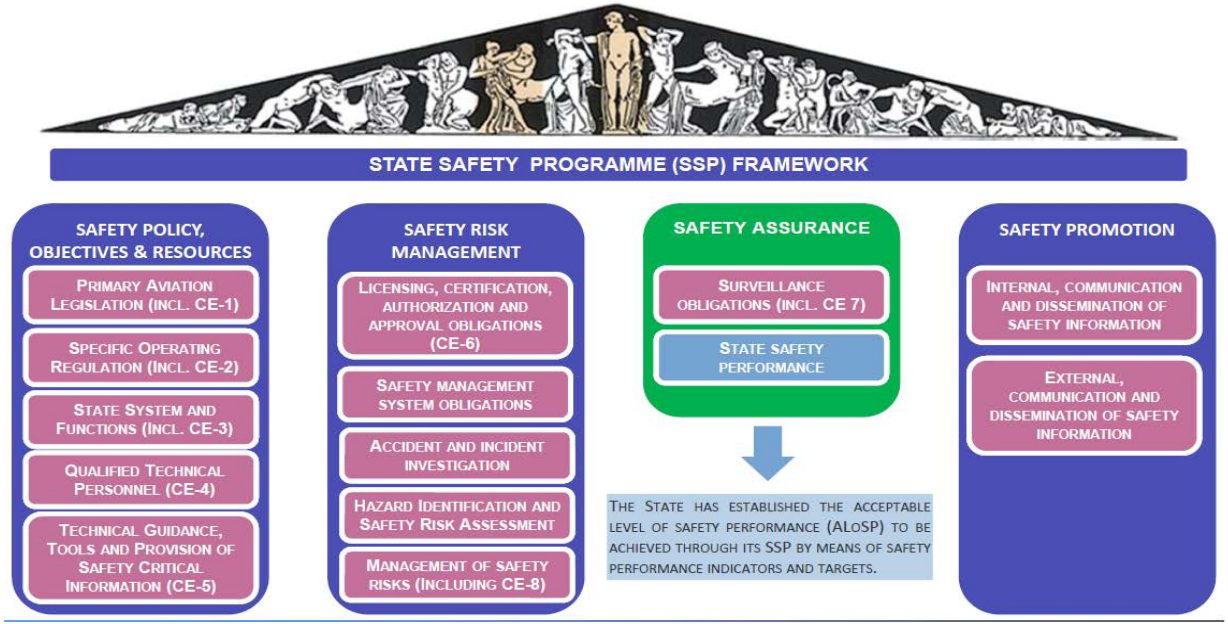
Module 4: Safety Performance Monitoring

- INTRODUCTION
  - Background
  - SMS framework
- SAFETY PERFORMANCE INDICATORS
  - SELECTION
- RISK ASSESSMENT
  - AGGREGATED RISK
  - SIRA
- TREND ANALYSIS
  - AGGREGATED RISK
  - SAFETY TARGETS
- CONCLUSIONS

SMS Framework

Introduction

SMS Framework



SMS Framework

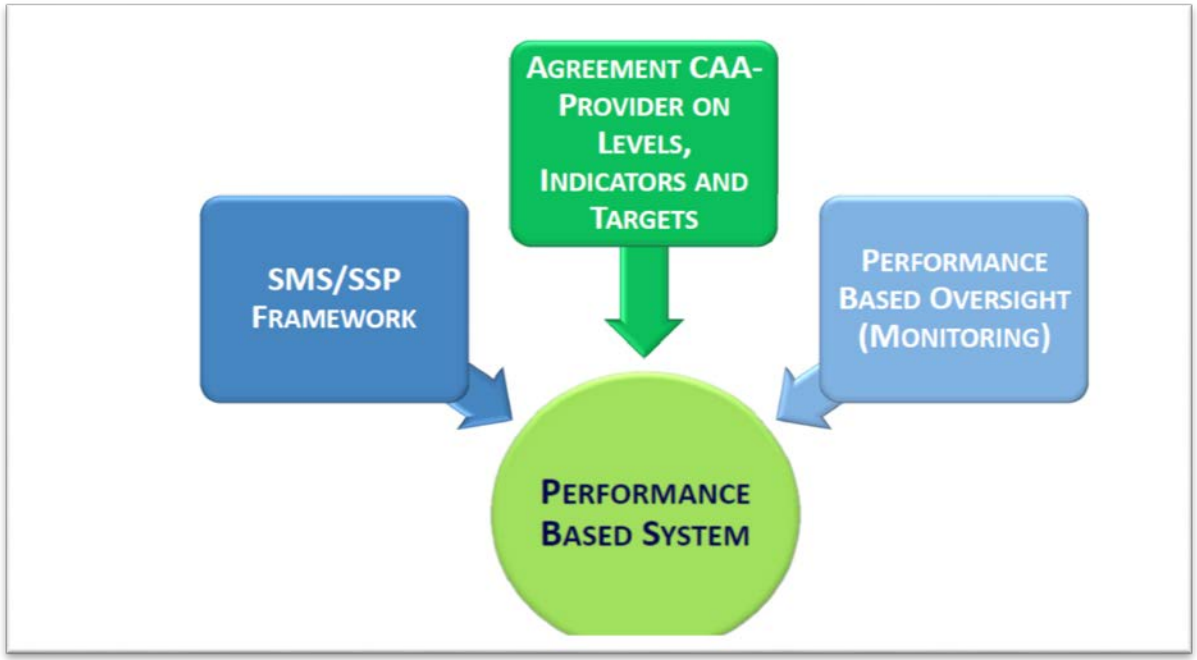
- Safety assurance is based on the application of the principles of quality management to the control and mitigation of hazards that threaten the operation of a system

- 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)



ICAO Annex 19 – Safety Management

Definitions

Safety Performance: Safety achievement as defined by the safety performance targets and indicators.

Safety Performance Indicator: Data-base parameter used for monitoring and assessing safety performance

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

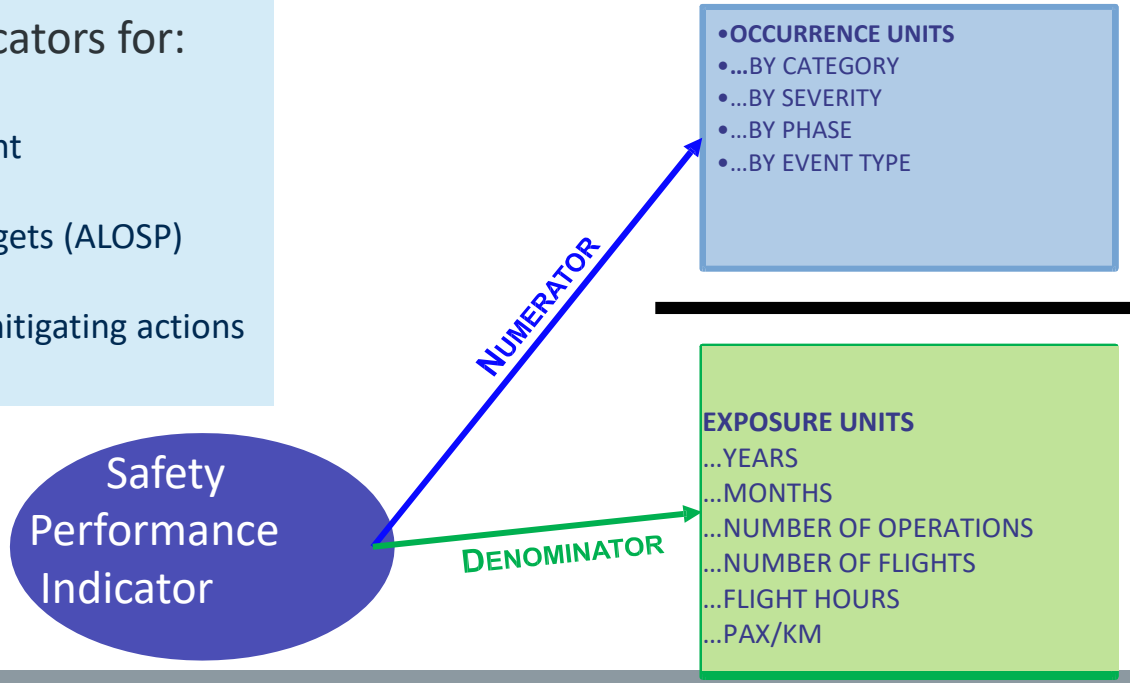
Concept

Safety Performance Indicators

Indicators provide meaningful information about the behavior of a system

What are safety performance indicators for:

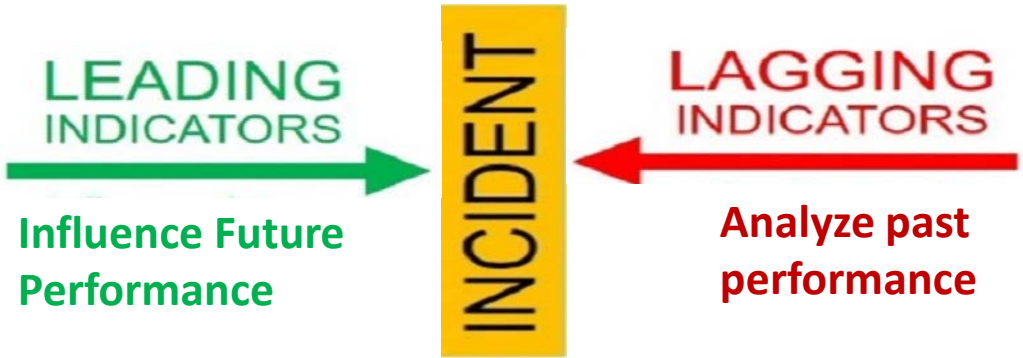
- Provide an objective safety measurement
- Essential for comparison with safety targets (ALOSP)
- Measure the effect of implemented mitigating actions



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

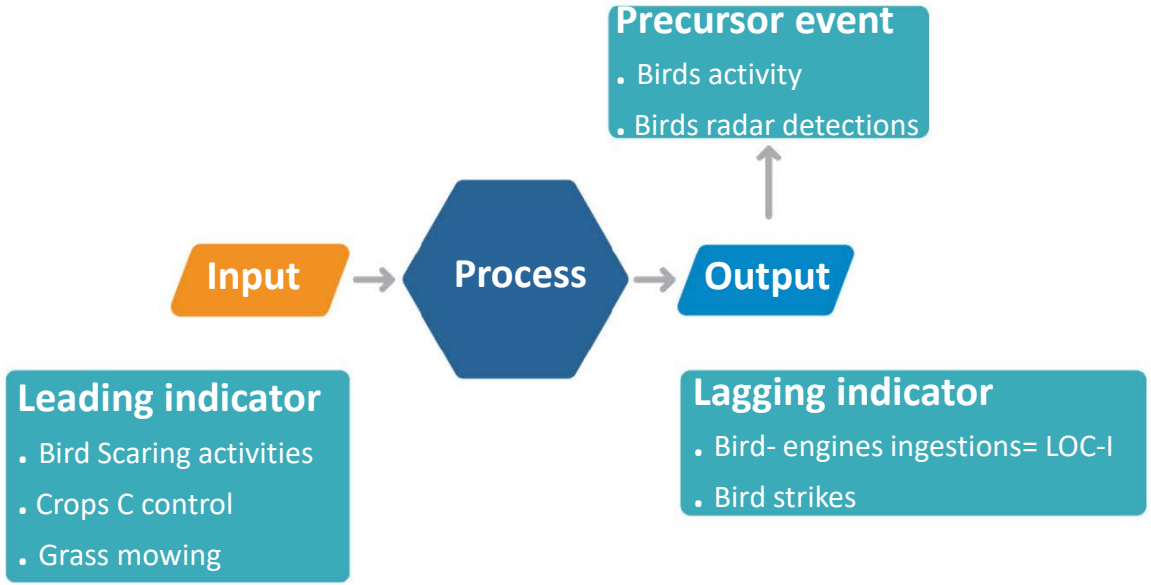
Lagging Vs leading indicators



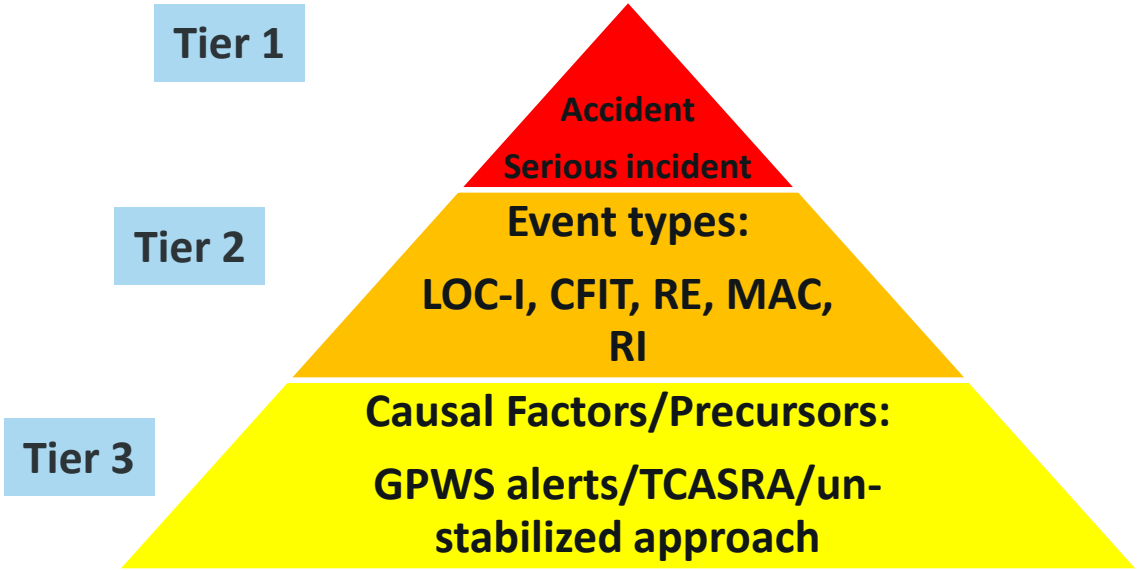
Leading SPIs measure processes and inputs being implemented to improve or maintain safety. Also known "activity or process SPIs" as they monitor and measure conditions that have the potential to become or contribute To a specific outcome

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



Lagging indicators



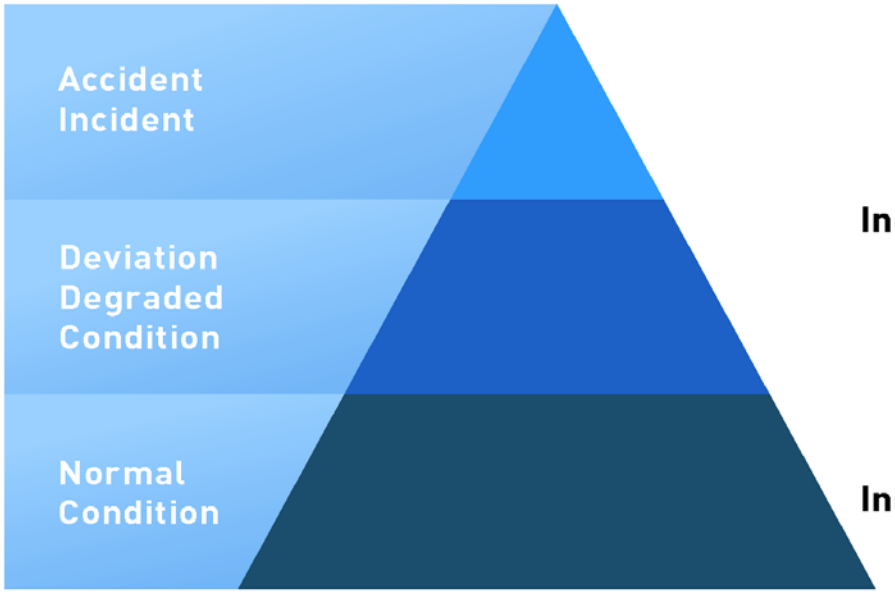
Lagging indicators

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



Lagging Indicators

- Number of runway excursions/1000 landings
- Precursor Events
  - Number of unstabilized (or non-compliance) approaches/1000 landings

Leading Indicators

- Percentage of pilots who have received training in stabilized approach procedures

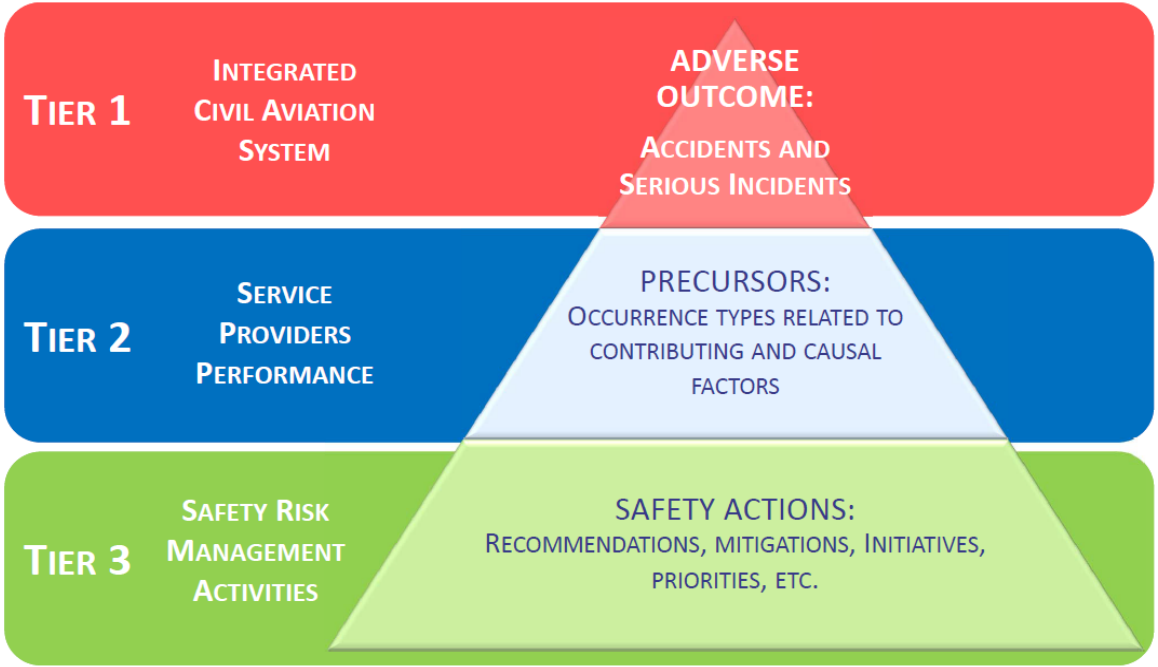
Combined leading and lagging indicators provide a more comprehensive and realistic picture of the organization's safety performance.

Defining SPIs: Each SPI should include

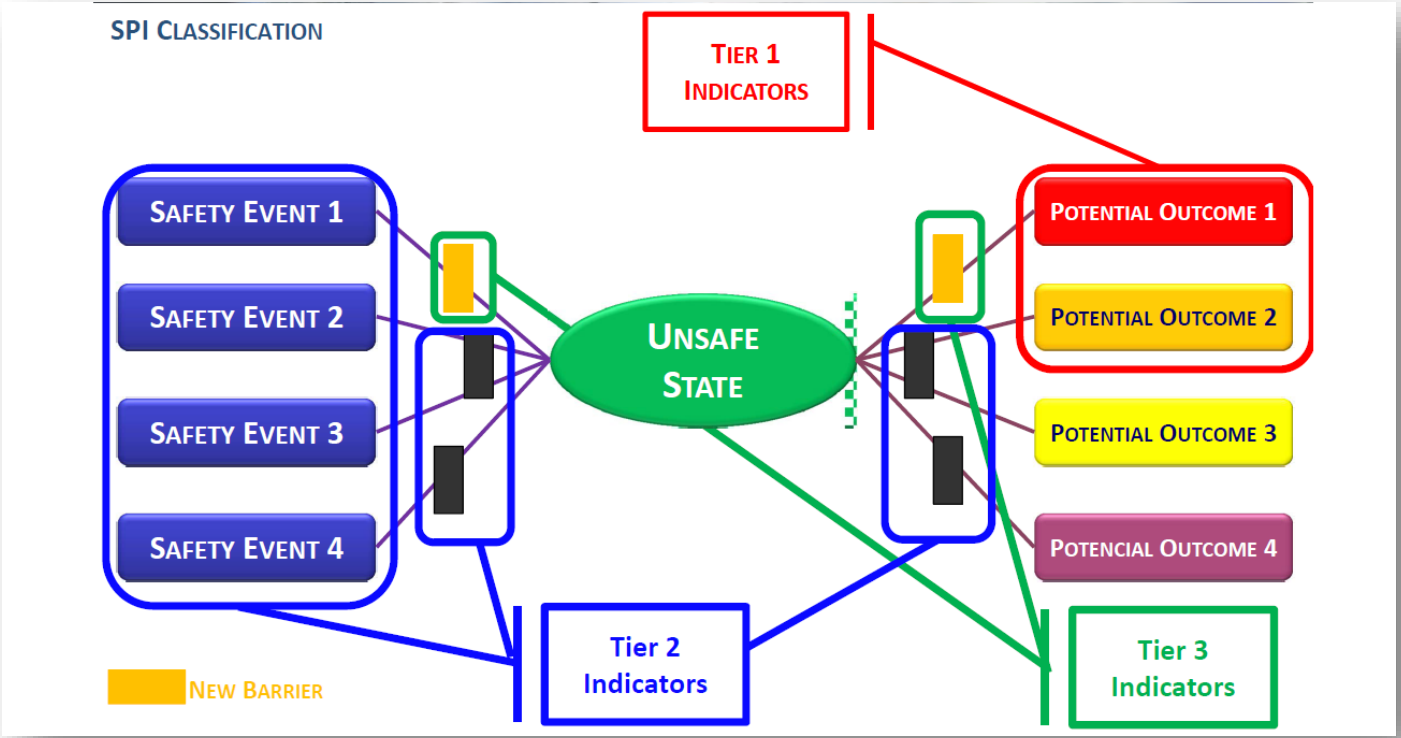
- a description of what the SPI measures
- the purpose of the SPI (what it is intended to manage and who it is intended to inform);
- the units of measurement and any requirements for its calculation;
- who is responsible for collecting, validating, monitoring, reporting and acting on the SPI
- where 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



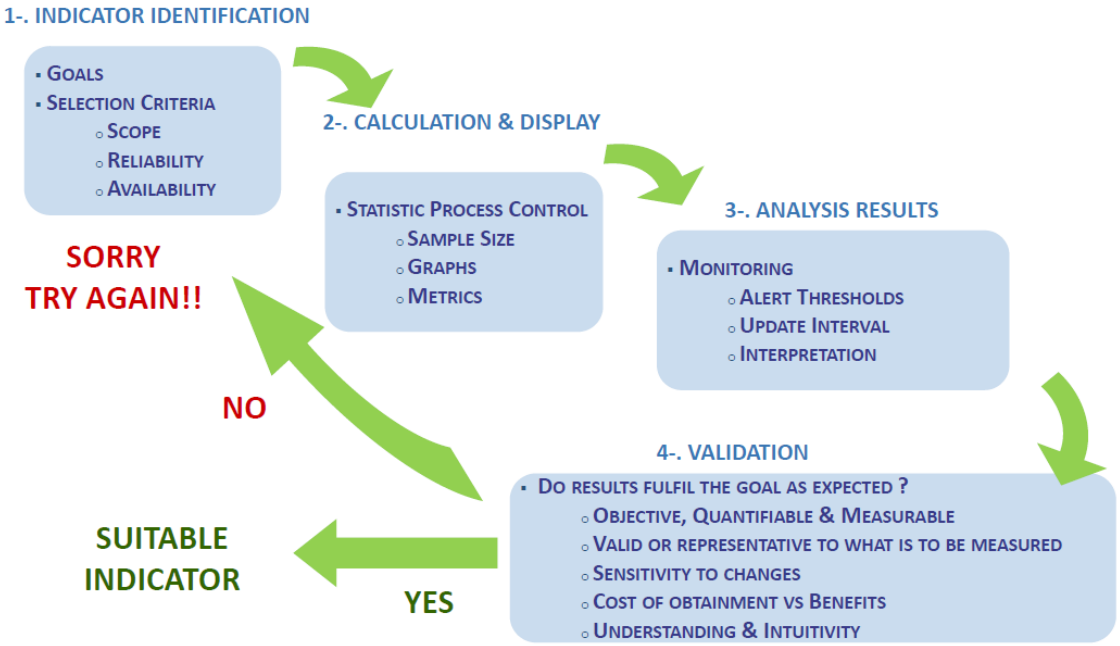
SPI Classification

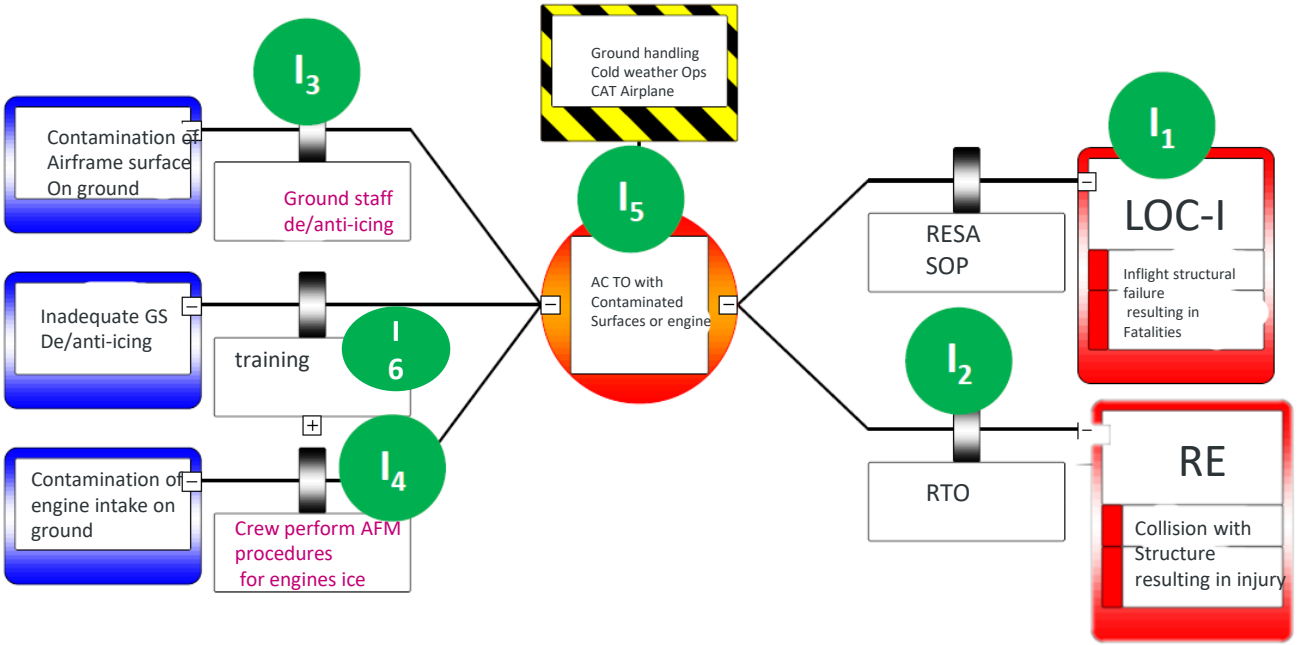


SPI Classification

Level	SPI	
Tier 1	SPI 1	Large Commercial Transport Aircraft Accidents / 10^6 Flights
	SPI 2	Large Commercial Helicopter Accidents / 10^6 Flights
	SPI 5	General Aviation Accidents / 10^6 Flights
Tier 2	LOC-I	Stick shaker / Increased roll attitude or rate / High pitch angle / Overspeed (vertical or configuration) / Failure of primary flight instruments (rates)
	CFIT	EGPWS hard warnings / Descent below MSA / Navigation errors (rates)
	RE	Abnormal runway contact / Loss of control on ground / Long or fast landings / Occurrences with crosswind conditions / High speed rejected take-offs / ATA32 occurrences
	MAC	Losses of separation / Inadequate separation / Level Busts / Airspace Infringement (rates)
	RI-VAP	Runway Incursions (rates)
	G-COL	Taxiway incursions / Avoiding maneuvers during taxi / Aircraft collisions and collisions with aircraft (rates)
	SC-F	Engine failure / Flight control problems / Helicopter tail rotor and main rotor blade failures or malfunctions (rates)
Tier 3	SPI 6	Number of Courses / Safety Communications / Workshops to aware about specific safety issues
	SPI 7	% of the Operational Staff trained in accordance with updated SOPs

Selection Process




Ground handling
Cold weather Ops
CAT Airplane
I3
Contamination of
Airframe surface
On ground
Ground staff
de/anti-icing
I5
AC TO with
Contaminated
Surfaces or engine
I1
LOC-I
Inflight structural
failure
resulting in
Fatalities
RESA
SOP
Inadequate GS
De/anti-icing
training
I
6
I2
RTO
RE
Collision with
Structure
resulting in injury
Contamination of
engine intake on
ground
I4
Crew perform AFM
procedures
for engines ice

Concept

Aggregated Risk

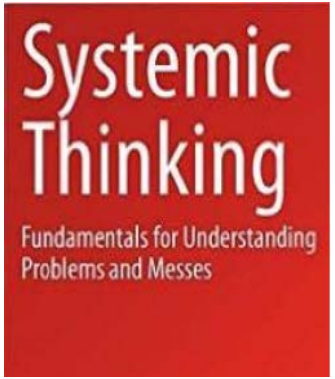
Term used in economics to measure the vulnerability of a system to catastrophic failures caused by events or conditions in intermediate stages.

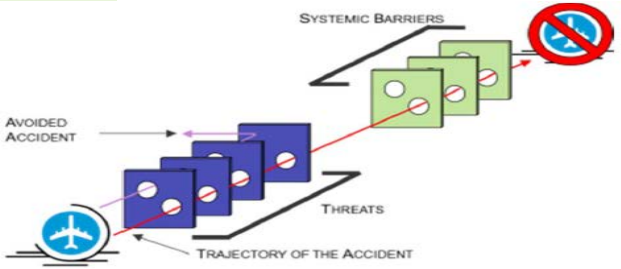
This concept can be easily extrapolated to aviation as a high level indication of the exposure of the aviation system to accidents, and used to monitor the safety performance with respect to safety targets.

Concept

Aggregated Risk

- 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)





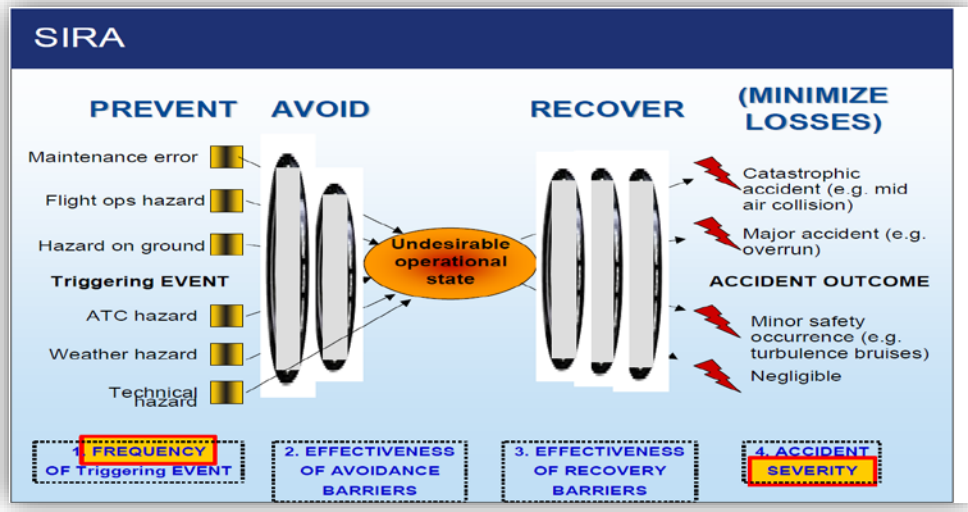
SIRA ARMS

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



ERC-SIRA/ARMS

ARMS in a Nutshell

ERC

Event Risk Classification — *First step for all incoming data*

HOW TO DO IT:

Question 2: What was the effectiveness of the remaining barriers between this event and the most credible accident scenario?				Question 1: If this event had escalated into an accident outcome, what would have been the most credible outcome?		Typical accident scenarios
Effective	Limited	Minimal	Not effective			
50	100	500	2500	Catastrophic Accident	Loss of aircraft or multiple fatalities (3 or more)	Loss of control, mid air collision, uncontrollable fire on board, explosive, total structural failure of the aircraft, collision with terrain
10	21	101	500	Major Accident	1 or 2 fatalities, multiple serious injuries, major damage to the aircraft	High speed taxiway collision, major turbulence injuries
2	4	20	100	Minor Injuries or damage	Minor injuries, minor damage to aircraft	Pushback accident, minor weather damage
1				No accident outcome	No potential damage or injury could occur	Any event which could not escalate into an accident, even if it may have operational consequences (e.g. diversion, delay, individual discomfort)

Answer Question 1:
- Think how the event could have escalated into an accident outcome (see examples to the right of the ERC matrix). Typically, the escalation could be due to actions by the people involved, the way the hazard interferes with the flight, and barrier behaviour.
- Do not filter out improbable scenarios. Question 2 will take the (low) probability into account.
- Among the scenarios with an accident outcome, pick the most credible, and select the corresponding row in the matrix.

Answer Question 2:
- To assess the remaining safety margin, consider both the number and robustness of the remaining barriers between this event and the accident scenario identified in Question 1.
- Barriers, which already failed are ignored
- Select the column of choice. See section 4.2 for detailed guidance.

RESULT:*

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

21 ERC Risk Index number → Use in database analysis (trending & statistics)

* Examples only. To be customised at each organisation.

Safety event/data
START HERE

Safety Assessment
START HERE

Quick Reference Guide

SIRA

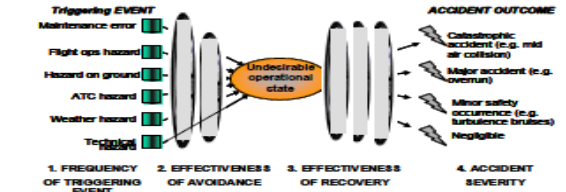
Safety Issue Risk Assessment

Used for:
- *Safety Issues*
- *Safety Assessments, when quantifiable (Management of Change process)*

HOW TO DO IT:

Define the Safety Issue precisely:
- Scope the issue in terms of hazards, locations, a/c types, etc. See section 4.8 for detail.

Develop the related potential accident scenarios:
- There may be several accident scenarios within one Safety Issue (see *glossary*)
- Select the most critical scenarios (one or more) for the risk assessment



Analyse (each) Scenario using the SIRA model (above):
- Identify the accident outcome of the scenario
- Identify what is considered the triggering event (see section 6.9 for detail)
- Decide what you consider as the UOS.
- List the avoidance and recovery barriers and review their robustness

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

RESULT:* *(see section 4.8 for detail)*

- → "Stop": Discontinue the concerned part of the operation until acceptable risk level.
- → "Improve": Still unacceptable risk but tolerable for a short time. Action required.
- → "Secure": Frequent monitoring required, as the item is at the limit of acceptable.
- → "Monitor": Monitor through the routine database analysis.
- → "Acceptable". No specific action required.

ARMS Working Group Final Report 2007-2010

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

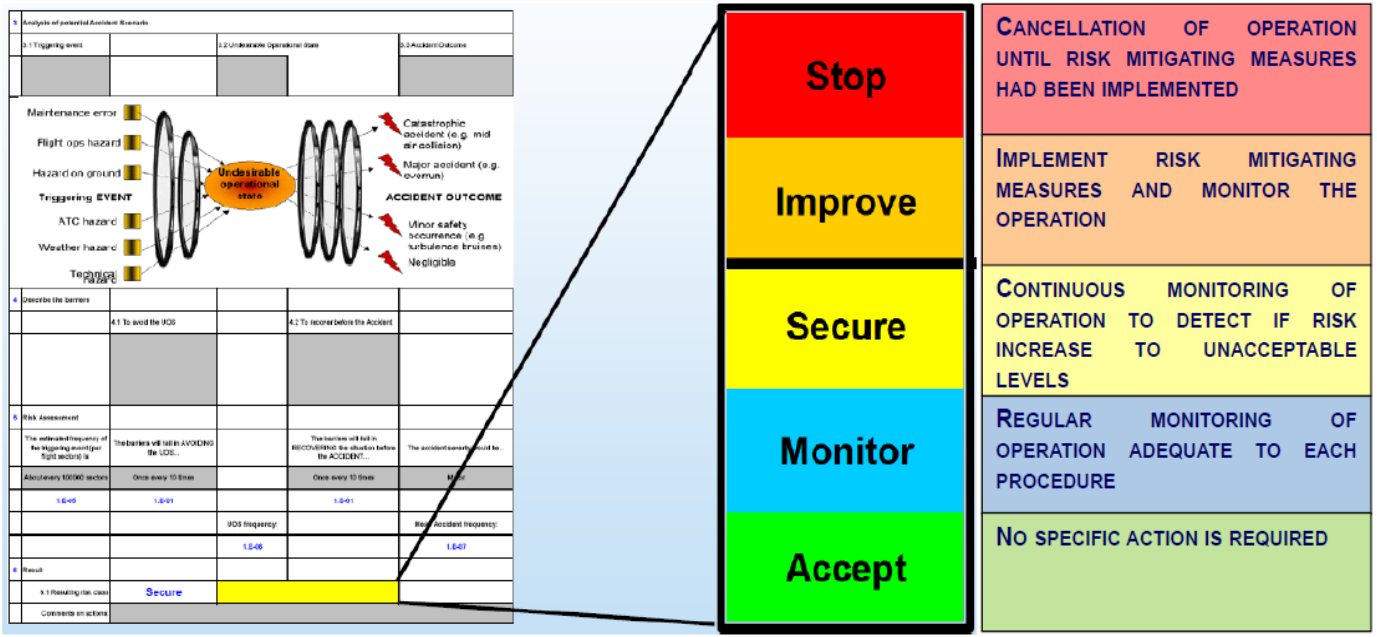
3. Analyze (each) Scenario using the SIRA model

- 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

SIRA Spreadsheet



SIRA: METRICS

Estimated frequency of the initial event (per flight sectors) is:		The barriers will fail in AVOIDING the UE...		The barriers will fail in RECOVERING the situation before the ACCIDENT...		The accident severity would be...	Tolerability limit	Short definition
Virtually every flight	1,E+00	Practically always	1,E+00	Practically always	1,E+00	Catastrophic	1,E-09	3 fatalities or more
Almost every flight	1,E-01	Once every 10 times	1,E-01	Once every 10 times	1,E-01	Major	1,E-07	Serious injuries
About every 100 sectors	1,E-02	Once in 100 times	1,E-02	in 100 times	1,E-02	Minor	1,E-05	Minor injuries
1.000 sectors	1,E-03	in 1.000 times	1,E-03	in 1.000 times	1,E-03	Negligible	1,E+00	Negligible
10.000 sectors	1,E-04	in 10.000 times	1,E-04	in 10.000 times	1,E-04			
100.000 sectors	1,E-05	in 100.000 times	1,E-05	in 100.000 times	1,E-05			
1M sectors	1,E-06	in 1M times	1,E-06	in 1M times	1,E-06			
10 M sectors	1,E-07	in 10M times	1,E-07	in 10M times	1,E-07			

SAFETY ANALYSIS TECHNIQUES

Trend Analysis

SAFETY SCREENING

- 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

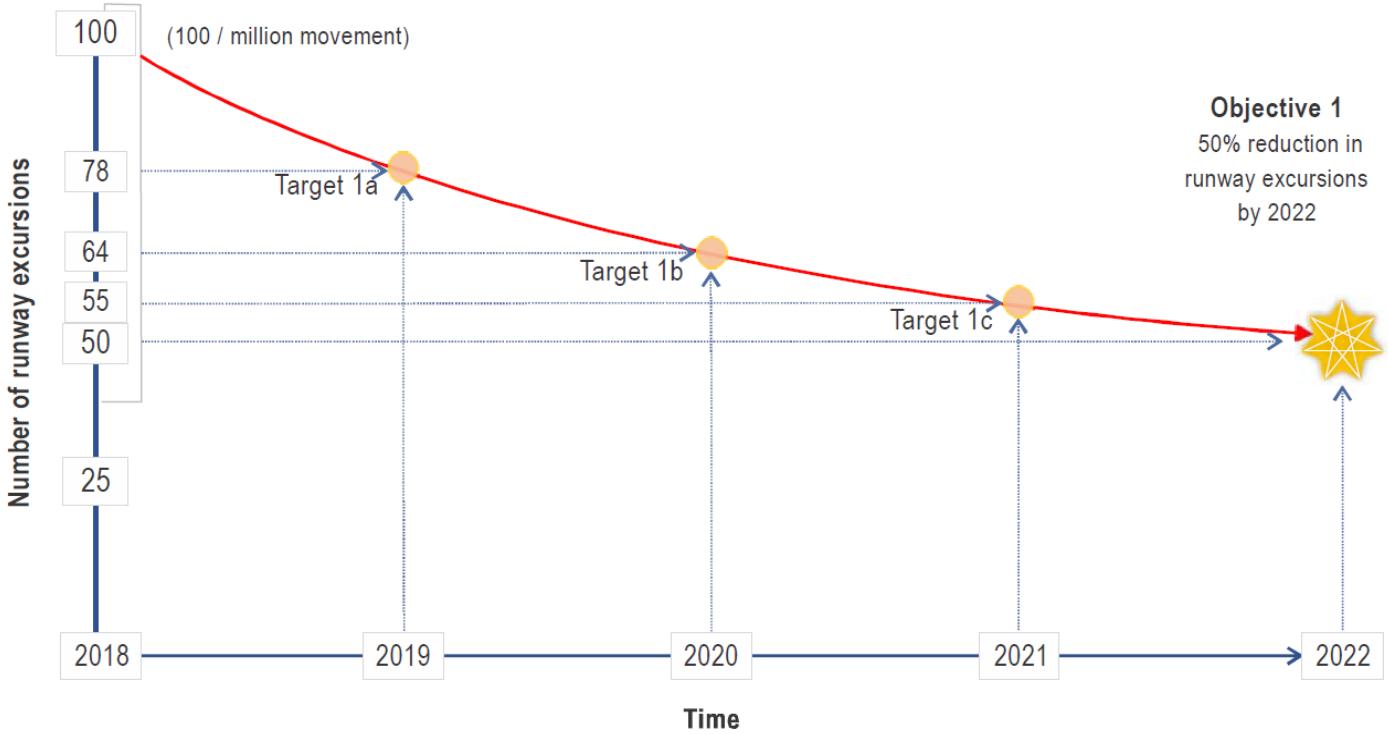
TREND ANALYSIS

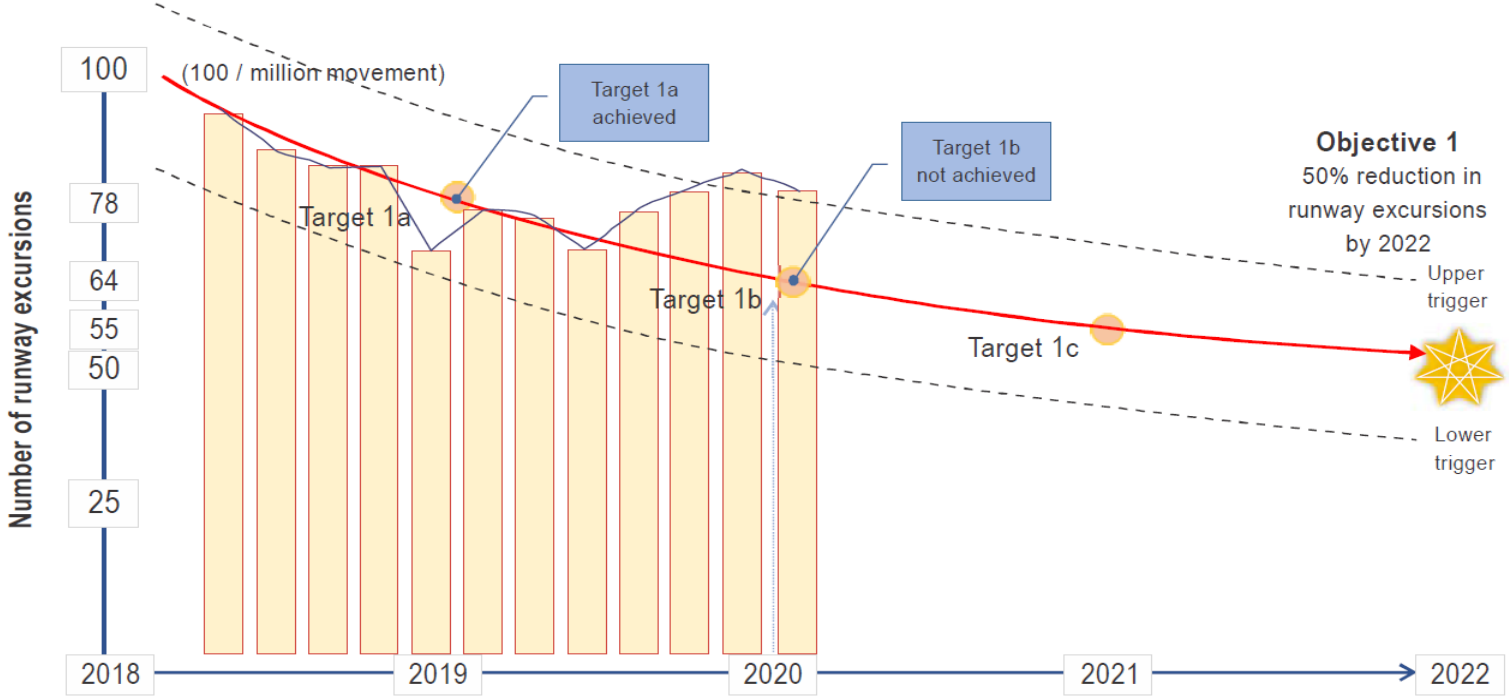
- IDENTIFICATION OF SAFETY PERFORMANCE INDICATORS (SPI)
- STATISTICAL ANALYSIS OF SPI TIME SERIES

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

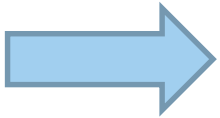



Number of runway excursions
100
78
64
55
50
25
(100 / million movement)
Target 1a achieved
Target 1b not achieved
Target 1a
Target 1b
Target 1c
Objective 1
50% reduction in runway excursions by 2022
Upper trigger
Lower trigger
2018
2019
2020
2021
2022

Applicable Techniques

Trend analysis:

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



Times series

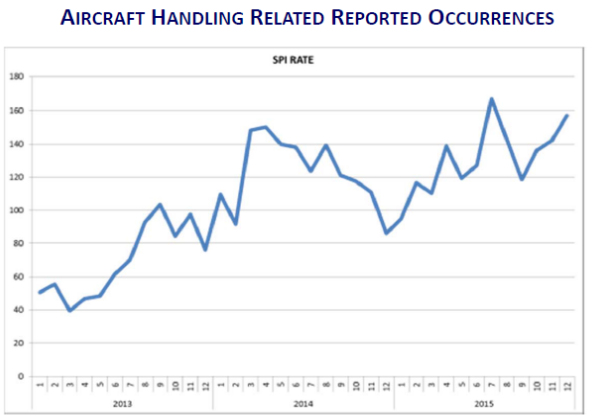
statistical analysis:

- 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

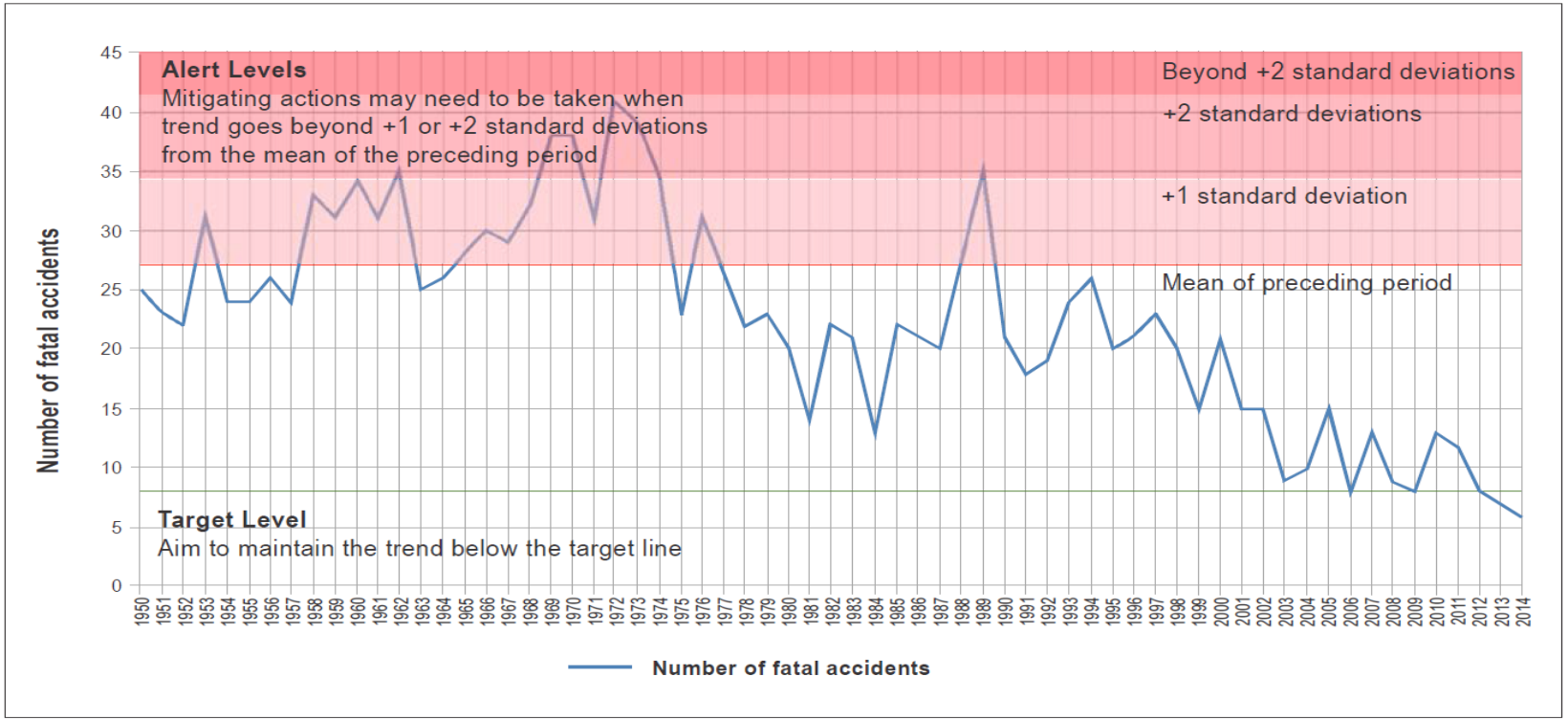
Alert Limits

Time Series

YEAR	MONTH	OCCURRENCES	EXPOSURE	SPI RATE
2013	1	42	82.990	50,6
	2	43	77.647	55,4
	3	35	88.361	39,6
	4	37	78.869	46,9
	5	44	91.085	48,3
	6	57	92.339	61,7
	7	70	99.604	70,3
	8	88	94.839	92,8
	9	90	86.817	103,7
	10	69	81.763	84,4
	11	67	68.692	97,5
	12	51	66.860	76,3
2014	1	71	64.798	109,6
	2	55	59.970	91,7
	3	101	68.164	148,2
	4	114	75.931	150,1
	5	114	81.557	139,8
	6	116	84.012	138,1
	7	116	93.808	123,7
	8	124	89.143	139,1
	9	99	81.716	121,2
	10	92	78.340	117,4
	11	77	69.479	110,8
	12	59	68.411	86,2
2015	1	60	63.224	94,9
	2	71	60.863	116,7
	3	81	73.473	110,2
	4	108	77.862	138,7
	5	99	82.997	119,3
	6	111	87.365	127,1
	7	160	95.685	167,2
	8	131	91.762	142,8
	9	101	85.220	118,5
	10	111	81.516	136,2
	11	98	69.052	141,9
	12	110	70.068	157,0

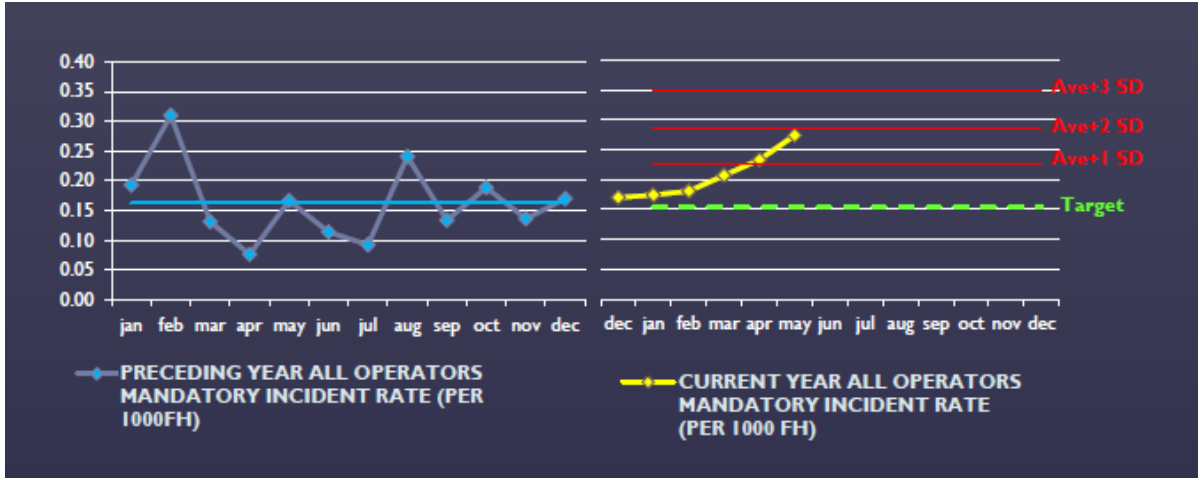


Example of representation of safety triggers (alert) levels



Two SPI Performance Markers

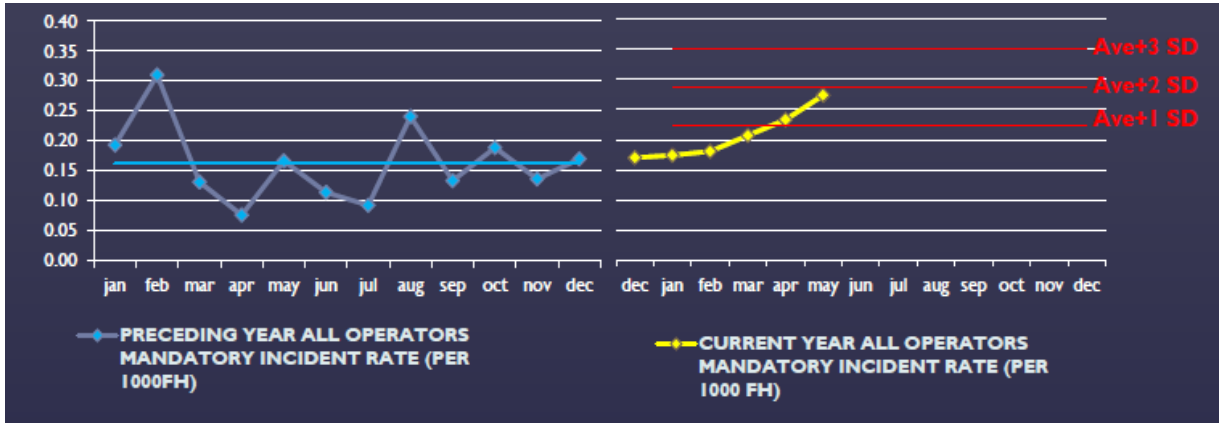
- Establish high occurrence rate **Alert trigger** within each SPI
- Establish planned improvement **Target level** within each SPI



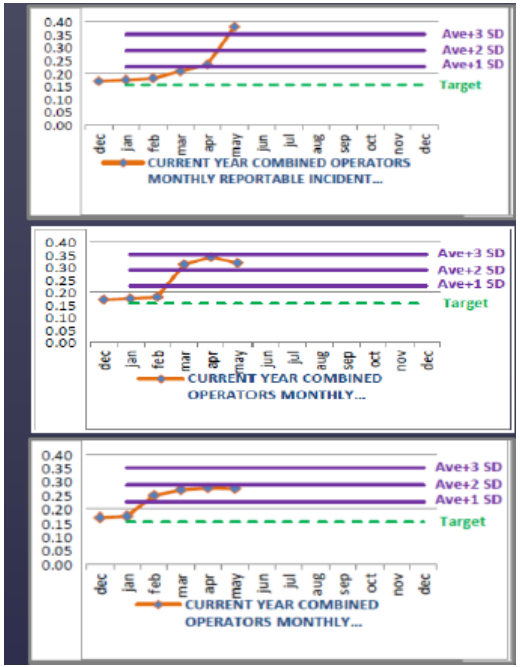
"what gets measured gets noticed."

Alert Trigger setting

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



Alert Trigger setting – 3 criteria



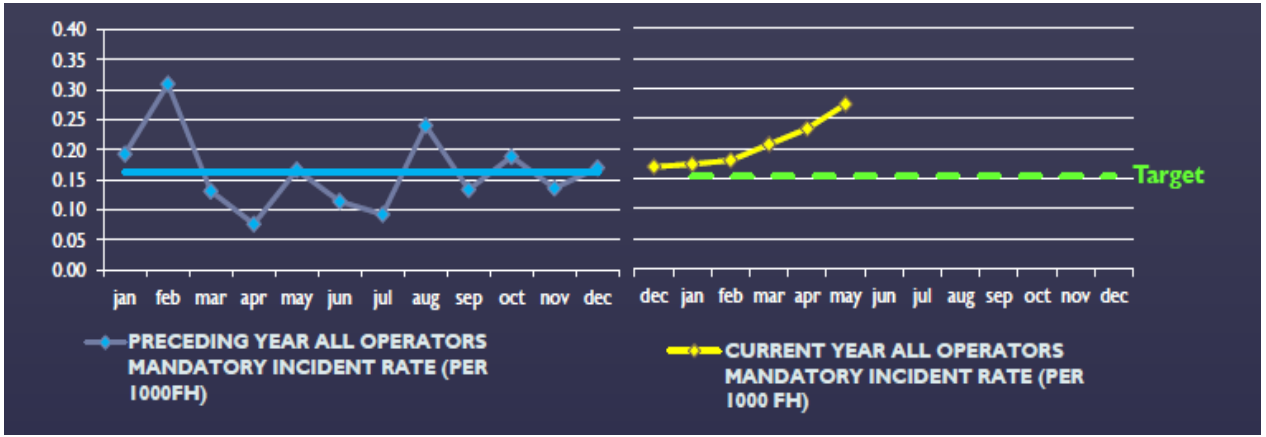
One single point above 3- SD line

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



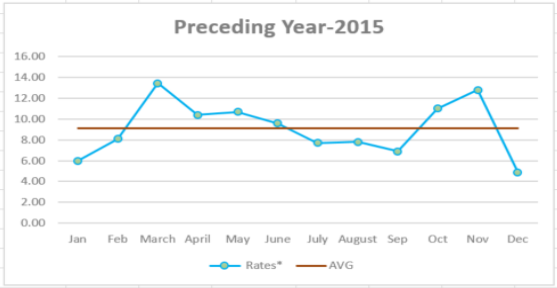
Example

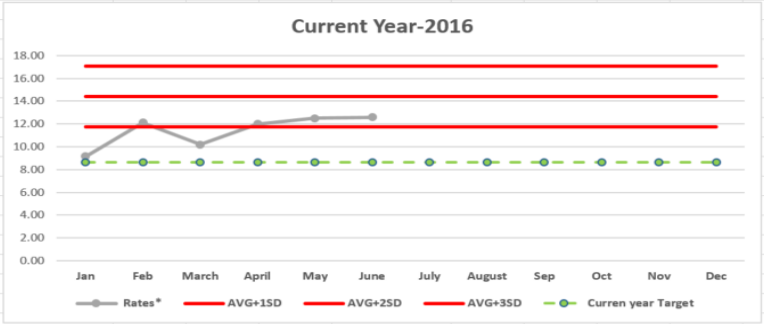
Preceding Year-2015					Current Year-2016				Current Year Alert Levels			Curren year
Month	OCC	FH	Rates*	AVG	Month	OCC	FH	Rates*	AVG+1SD	AVG+2SD	AVG+3SD	Target
Jan			6.00	9.11	Jan			9.14	11.77	14.42	17.08	8.66
Feb			8.10	9.11	Feb			12.11	11.77	14.42	17.08	8.66
March			13.45	9.11	March			10.19	11.77	14.42	17.08	8.66
April			10.40	9.11	April			12.00	11.77	14.42	17.08	8.66
May			10.69	9.11	May			12.50	11.77	14.42	17.08	8.66
June			9.59	9.11	June			12.60	11.77	14.42	17.08	8.66
July			7.72	9.11	July				11.77	14.42	17.08	8.66
August			7.80	9.11	August				11.77	14.42	17.08	8.66
Sep			6.89	9.11	Sep				11.77	14.42	17.08	8.66
Oct			11.02	9.11	Oct				11.77	14.42	17.08	8.66
Nov			12.81	9.11	Nov				11.77	14.42	17.08	8.66
Dec			4.90	9.11	Dec				11.77	14.42	17.08	8.66
		AVG	9.11									
		SD	2.66									

AVG+1SD	AVG+2SD	AVG+3SD
11.77	14.42	17.08

Curent year alert level setting criteria is : Preceeding year AVG+1/2/3/SD

Current year target is say 5% Ave rate improvement over the AVG ratefor the preceeding year which is **8.66**

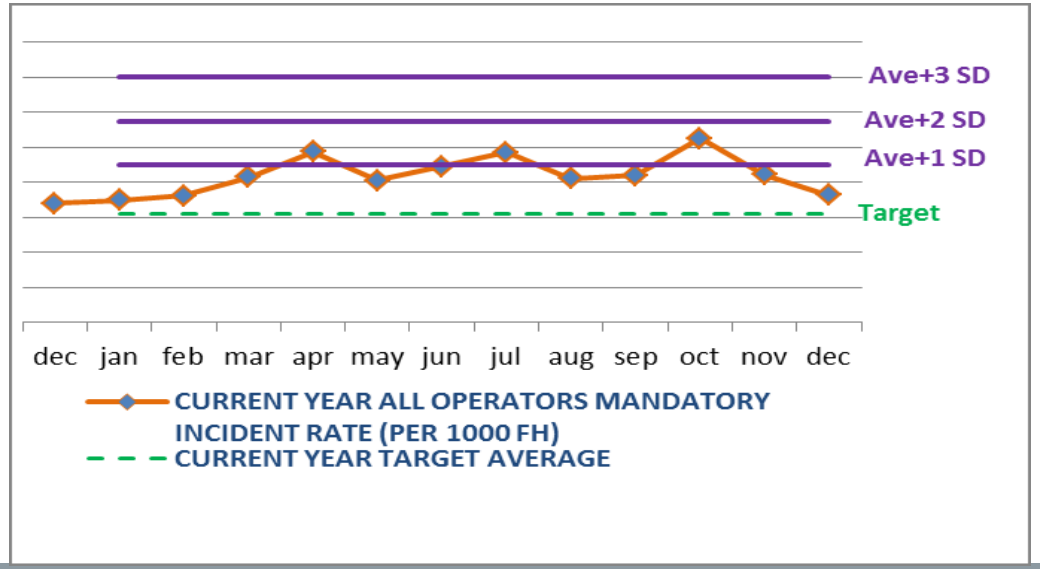




Target Monitoring

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:

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(HEADQUARTERS)

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SUB-OFFICE)

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DAKAR
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(ASIA-PACIFIC)

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LIMA
(SOUTH AMERICA)

THANK YOU!