An Overview of ICAO Safety Management for Practitioners (SMxP) Course

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ICAO Safety Management Training Programme

This new SMxP Course consists of 2 parts:

a) On line course, provides knowledge on basic concepts and includes five modules:

1) Safety Management Fundamentals;
2) Safety Management Provisions;
2A) Amendment 1 to Annex 19;
3A) State Safety Programme (SSP); and
3B) Safety Management Systems (SMS) Implementation.

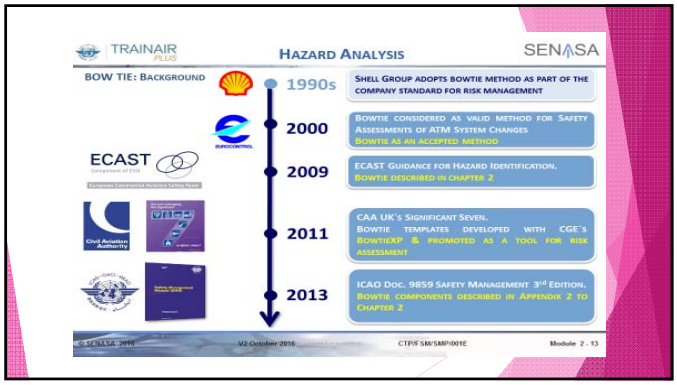
b) Safety Management for Practitioners course, focused on practicing SM processes.

Concentrated on the 2nd & 3rd SMS/SSP Framework Components:

- Safety Risk Management
- Safety Assurance

The course is supported by IT tools in which BowTieXP and Excel Spreadsheet has been selected as the IT solutions to be used in this course.

BowTieXP is unique in its ability to visualize complex risks in a way that is understandable, yet also allows for detailed risk based improvement plans.



The effectiveness of the course is measured through a partial application of Kirkpatrick´s model for evaluating the effectiveness of training.

It considers the value of any type of training, formal or informal, across four levels:

- Level 1 Reaction evaluates how participants respond to the training.
- Level 2 Learning measures if they actually learned the material.
- Level 3 Behavior considers if they are using what they learned on the job
- Level 4 Results evaluates if the training positively impacted the organization.

Hazards Identification & Analysis

Hazard:

A condition or object with the potential of causing injuries to personnel, damage to equipment or structures, loss of material, or reduction of ability to perform a prescribed function (SMM)

An undesirable condition or situation which may lead to unsafe events or occurrences (SMM)

A condition or an object with the potential to cause or contribute to an aircraft incident or accident (Annex 19, Amdt 1, Effective Date: 16th July 2016)

Something that, in case of failure, can lead to a negative outcome

A normal and identifiable system component (part of normal business), whose consequences are usually manageable.

Hazards could generally be classified as:

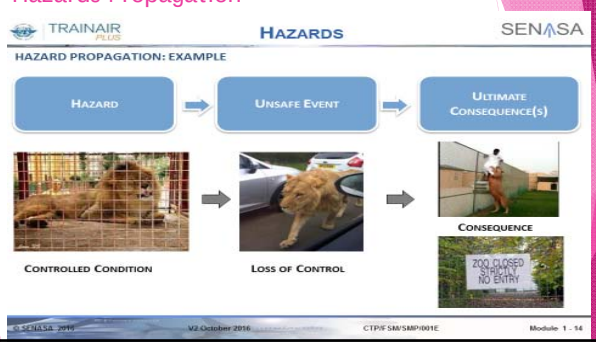
- **Environmental** Severe Weather or Climatic Events (Hurricanes, Typhoons, etc.), Adverse Weather (Fog, Ice, Low Visibility, etc.), Geographical Events (Volcanos, Earthquakes, etc.), Geography (Terrain, Altitudes, etc.), Natural Events (Wildlife, Fires, etc.), Public Health (Epidemics, etc.)
- **Technical Aircraft** (Ej: systems, subsystems, components & associated equipment), Organizational Facilities (Ej: tools, hangars, workshops, etc.), External Facilities (facilities and systems external to the operation), Physical Ergonomics (human characteristics associated to the physical activities of the operation).
- **Organizational (**Economics (Growth/Recession), Operational Policies & Procedures, Materials/Equipment acquisition, Organizational Culture).
- **Human (**Medical, Psychological, Cognitive, Physical Limitation)

Hazards Analysis

A structured hazard analysis should address these questions:

What is the Hazard?
Which events can produce it?
What happens when Hazard is released?
How can we reverse the situation?
How can the system propagate into an accident?
How can we avoid such adverse outcome?

Hazards Propagation



Hazards Analysis Methods

Failure Mode effect Analysis (FMEA)

Identifies the causes of failure and their effects on the function of a system

used extensively in the design of new equipment in the airworthiness domain'

Hazard Operability Study (HAZOP)

Systematic and structured approach based on group discussion, using parameter and deviation guidewords.

It supports the estimation of likelihood and consequences of events'

Fault Tree/Event Tree/Bow Tie Analysis

Graphical techniques that provide an alternative to block diagrams. Based on inductive / deductive approach structured in terms of events, that can be assigned to causes and consequences The analysis is carried out along a tree path.

BowtieXP: Components

Hazard Something in, around or part of the system which has the potential to cause damage.

Unsafe State (Top Event) State when control is lost over the Hazard

Also known as Undesired State or Unsafe Event:

The first event in a chain of negative events leading to unwanted consequences

It is not a catastrophe yet, but now there is exposure to the potential harm of the hazard.

However, it should be possible to bring the situation under control again.

Safety Event (Triggering Event) Whatever will cause the Unsafe Event

Also known as Threats, Causes or Triggering Events

Barrier/Mitigation: Elements that interrupt the propagation so that the triggering event does not result in a Loss of Control of the Hazard or do not escalate into a potential outcome.

Also known as controls or mitigations. there are three different places for barriers :

- Between a Safety Event and the top event (preventive barriers – also known as proactive barriers)
- Between the top event and a consequence (recovery barriers, also known as reactive or defense barriers)
- Between a barrier and an escalation factor (escalation factor barriers)

Recovery Barriers: Aimed at regaining control once it is lost (Top Event has occurred). They act on the likelihood or severity of a potential consequence through:

- Control. Prevents the consequence from happening
- Mitigation. Does not prevent the consequence from happening, but lessens the severity of the consequence.

Consequence: Results from the Unsafe Event. Unwanted event resulting from the release of the Hazard.

Escalation Factor: Factors or conditions which make a barrier/mitigation to fail.

A condition that leads to increased risk by defeating or reducing the effectiveness of a Barrier.

Three escalation factor categories are:

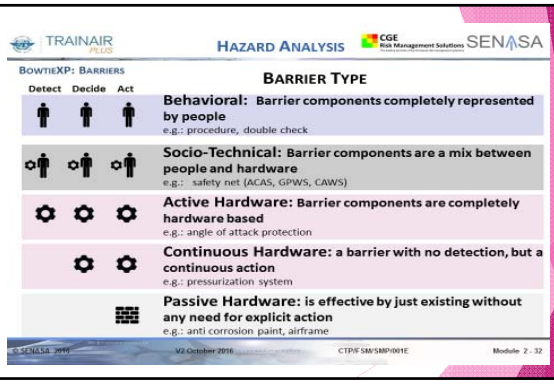
- Human factors: anything a person does to make a barrier less effective
- Abnormal conditions: anything in the environment that causes a barrier to be put under strain
- Loss of critical services: if a barrier relies on an outside service, losing that service might cause it to lose effectiveness

Escalation Factors Barriers:

Barrier that manages the conditions which reduce the effectiveness of other Barriers.

Escalation factor barriers are the same concept as all the previously discussed barriers, but now they do not prevent/mitigate a top event or consequence from happening, but they prevent a barrier from failing.

The same principles that apply to normal Barriers also apply to Escalation Factor Barriers.



In summary, the BowTieXP Components are:

TRAINAIR PLUS — HAZARD ANALYSIS — CGE Risk Management Solutions — SENASA

BOWTIEXP: COMPONENTS

TERM		MEANING
Hazard	HAZARD	SOMETHING IN, AROUND OR PART OF THE SYSTEM WHICH HAS THE POTENTIAL TO CAUSE DAMAGE
Top Event	UNSAFE STATE (TOP EVENT)	STATE WHEN CONTROL IS LOST OVER THE HAZARD
Safety Event	SAFETY EVENT (TRIGGERING EVENT)	WHATEVER WILL CAUSE THE UNSAFE EVENT
Barrier	BARRIER/MITIGATION	ELEMENTS THAT INTERRUPT THE PROPAGATION SO THAT THE TRIGGERING EVENT DOES NOT RESULT IN A LOSS OF CONTROL OF THE HAZARD OR DO NOT ESCALATE INTO A POTENTIAL OUTCOME.
Consequence	CONSEQUENCE	RESULTS FROM THE UNSAFE EVENT
Escalation Factor	ESCALATION FACTOR	FACTORS OR CONDITIONS WHICH MAKE A BARRIER/MITIGATION TO FAIL

Risk Assessment

In addition to the traditional ICAO 5 by 5 RA Matrix, ERC (4 by 4 Matrix) has been introduced:

Question 2

What was the effectiveness of the remaining barriers between this event and the most credible accident scenario?

Effective	Limited	Minimal	Not effective
50	102	502	2500
10	21	101	500
2	4	20	100
1			

Question 1

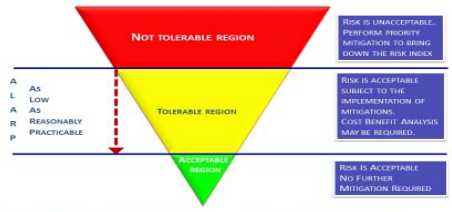
If this event had escalated into an accident outcome, what would have been the most credible outcome?

Catastrophic Accident	Loss of aircraft or multiple fatalities (3 or more)
Major Accident	1 or 2 fatalities, multiple serious injuries, major damage to the aircraft
Minor Injuries or damage	Minor injuries, minor damage to aircraft
No accident outcome	No potential damage or injury could occur

Tolerability: ALARP

TRAINAIR PLUS — RISK ASSESSMENT AND MITIGATION — SENASA

TOLERABILITY: ALARP



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Safety Screening

SENASA

Risk Classification

- Airline Risk Management Solutions (ARMS) is a methodology aimed to produce a useful and cohesive Operational Risk Assessment method for airlines and other aviation organisations
- Event Risk Classification (ERC) is an ARMS deliverable, aimed at the preliminary review of reported events in terms of prioritization and a risk allocation
- ERC value based on the answer to two questions:
  - Q1 looks to identify the accident outcome that is of most concern when this type of event occurs.
  - Q2 only considers remaining barriers to estimate the probability of further escalation into the most credible accident outcome
- ERC application is a 4x4 matrix, where risk estimation corresponds to the area of intersection of the two questions

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Safety Screening

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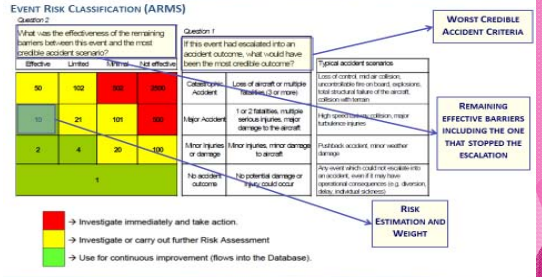
Event Risk Classification (ARMS)



Concept of Aggregate Risk in SPMM

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Aggregate Risk

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Concept

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

Aggregate Risk

- **Environmental Risk**
  - Severe Weather
  - Injuries
  - Lawsuits
- **Operations Risk**
  - System Failures
  - Human Factor
  - Organizational Drift
- **Financial Risk**
  - Credit Risk
  - Market Risk
  - Interest Rates
- **Strategic Risk**
  - Regulation
  - Reputation
  - Competition

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.

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AGGREGATE RISK

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CONCEPT

- IT CAN BE USED AS A HIGH LEVEL SPI TO MEASURE SAFETY PERFORMANCE
- AGGREGATE RISK CAN BE CALCULATED AS THE PRODUCT OF THE DIFFERENT COMBINATION OF FACTORS OF A BOWTIE DIAGRAM (SAFETY EVENTS, PREVENTION & RECOVERY CONTROLS)

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AGGREGATE RISK

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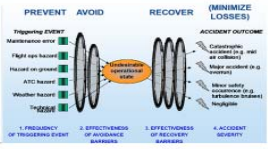
SIRA/ARMS

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



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AGGREGATE RISK

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SIRA: SPREADSHEET

Stop	CANCELLATION OF OPERATION UNTIL RISK MITIGATING MEASURES HAD BEEN IMPLEMENTED
Improve	IMPLEMENT RISK MITIGATING MEASURES AND MONITOR THE OPERATION
Secure	CONTINUOUS MONITORING OF OPERATION TO DETECT IF RISK INCREASE TO UNACCEPTABLE LEVELS
Monitor	REGULAR MONITORING OF OPERATION ADEQUATE TO EACH PROCEDURE
Accept	NO SPECIFIC ACTION IS REQUIRED

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AGGREGATE RISK

CGE Risk Management Solutions SENASA

LOPA

- LOPA IS A SEMI-QUANTITATIVE RISK ANALYSIS IN WHICH THE FREQUENCY OF A NEGATIVE EVENT IS CALCULATED ACCORDING TO THE RISK REDUCTION BY THE INDEPENDENT BARRIERS.
- AFTER ESTIMATING THE FREQUENCY OF A CONSEQUENCE, THE LOPA PLUG-IN ALLOWS TO FILL IN THE INITIAL FREQUENCIES OF THE SAFETY EVENTS AND THE PROBABILITY OF FAILURE ON DEMAND (PFD) FOR THE BARRIERS.
- TARGET FREQUENCIES CAN BE ADDED FOR THE CONSEQUENCES AND THE TOP EVENT. THE SOFTWARE THEN AUTOMATICALLY CALCULATES THE RELEVANT NUMBERS, LIKE THE CONSEQUENCE FREQUENCY, AND DISPLAYS THEM ON THE BOWTIE IF REQUIRED.

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AGGREGATE RISK

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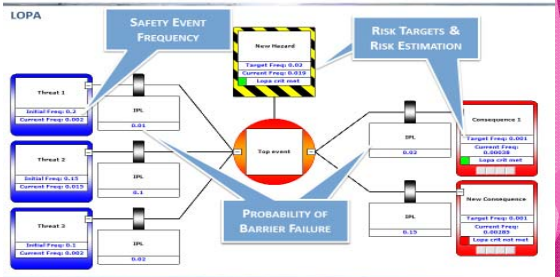
LOPA



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TREND ANALYSIS

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TIME SERIES ANALYSIS

TIME SERIES:

- SET OF ORDERED VALUES (SAFETY PERFORMANCE INDICATOR) IN TIME
- THE OBJECTIVE OF THE ANALYSIS IS TO DESCRIBE THE EVOLUTION OF A VARIABLE OVER TIME AND INTERPRET THEIR BEHAVIOR
- THE TIME-SERIES ANALYSIS METHODS ARE LARGELY BASED ON THE ASSUMPTION THAT HISTORICAL PATTERNS WILL CONTINUE, AND THEY RELY HEAVILY ON THE AVAILABILITY OF HISTORICAL DATA
- REFERENCES ABOUT APPLICABLE METHODS CAN BE FOUND IN ICAO DOC. 8991 (MANUAL ON AIR TRAFFIC FORECASTING) AND CAA UK'S CAP 739 (FLIGHT DATA MONITORING)

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TREND ANALYSIS

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TIME SERIES ANALYSIS

TIME SERIES ANALYSIS

- TREND PROJECTION
- DECOMPOSITION METHODS
  - MOVING AVERAGES
  - EXPONENTIAL SMOOTHING
  - BOX JENKINS
  - ADAPTIVE FILTERING
  - SPECTRAL ANALYSIS

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TREND ANALYSIS

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TREND PROJECTION

		LINEAR SCALE	LOG SCALE
$y = a + bx$	LINEAR TREND		
$y = ax^b$	EXPONENTIAL TREND		
$y = a + bx + cx^2$	PARABOLIC TREND		
$y = ka^{bx}$	GOMPERZ TREND		

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TREND ANALYSIS

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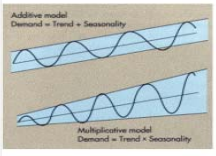
TREND DECOMPOSITION

- TIME SERIES MAY FOLLOW:
  - ADDITIVE MODELS, WHERE AN IMPLICIT ASSUMPTION THAT THE DIFFERENT COMPONENTS AFFECT THE TIME SERIES ADDITIVELY

    Y = TREND + SEASON + CYCLIC + RESIDUAL
  - MULTIPLICATIVE MODELS WHERE THE DIFFERENT COMPONENTS AFFECT THE TIME SERIES PROPORTIONALLY:

    Y = TREND X SEASON X CYCLIC X RESIDUAL
  - BY TAKING LOGARITHMS (EITHER NATURAL LOGARITHMS OR TO BASE 10), THE FOUR COMPONENTS OF THE MULTIPLICATIVE MODEL ACT ADDITIVELY



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Trend Analysis

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Alert Levels

- In conjunction with indicators based time series, alert (as well as safety targets) should be set. Alert levels will serve as markers to define what is the abnormal/unacceptable data rate
- For a new monitoring period (e.g: current year) alert levels will be based on the preceding period's performance (e.g: preceding year) through the calculation of average (M) and standard deviation (σ)
- 3 alert lines are defined: M + 1 σ, M + 2 σ and M + 3 σ.
- An alert (abnormal/unacceptable trend) is triggered if any of the conditions below are met:
  - Any single point is above the 3 σ line
  - 2 consecutive points are above the 2 σ line
  - 3 consecutive points are above the 1 σ line.
- Then appropriate follow-up action is expected, such as further analysis to determine the source and root cause of the undesired rate.

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Safety Targets

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Target Monitoring

SPI Monitoring

At the end of the monitoring period, each SPI is measured against:

- Target achieved (Yes/No)
- Alerts Breached (Yes /No)

This may allow a summary score (or percentage) to be obtained to indicate the overall performance of the ALoSP safety indicators at the end of any given monitoring period

Conclusion

BowTieXP: Added Value

Bowtie provide benefits to Safety Management processes due to:

- Effective, visual depiction of Hazard components
- Balanced overview for internal and external stakeholders (including third party risks)
- Increased awareness and understanding of the hazards leading to accident scenarios.
- Best practice guidance material for safety risk management at an operational and regulatory level.
- Identification of critical risk controls and an assessment of their effectiveness

END

THANK YOU

Q & A

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