AC 145-11(0)
1 February 2017

Civil Aviation Authority of Singapore

Advisory Circular

SAFETY MANAGEMENT SYSTEM – FRAMEWORK FOR THE ESTABLISHMENT OF SAFETY PERFORMANCE INDICATORS FOR APPROVED MAINTENANCE ORGANISATIONS

1. **GENERAL.** Pursuant to paragraph 88B of the Air Navigation Order, the Director General of the Civil Aviation Authority of Singapore (DGCA) may, from time to time, issue advisory circulars (ACs) on any aspect of safety in civil aviation. This AC contains information about standards, practices and procedures acceptable to CAAS. The revision number of the AC is indicated in parenthesis in the suffix of the AC number.

2. **PURPOSE.** This AC is issued to provide general guidance and principles on the development of Safety Performance Indicators (SPIs) for the Safety Management System (SMS) of an Approved Maintenance Organisation (AMO). This AC is meant to complement AC 1-3 that provides guidance on the key concepts and components of an SMS based on ICAO Standards and Recommended Practices and international practices.

3. **APPLICABILITY.** This AC applies to all SAR-145 Approved Maintenance Organisations (except SAR-145, Subpart D organisations).

4. **CANCELLATION.** Not Applicable.

5. **EFFECTIVE DATE.** This AC is effective on 1 April 2017.

6. **REFERENCES.** ICAO Annex 19, ICAO Safety Management Manual (Doc 9859), ICAO Circular 216-AN31, SAR-145.64 and CAAS AC 1-3.

7. **ICAO DEFINITIONS**

High-consequence indicators. Safety performance indicators pertaining to the monitoring and measurement of high-consequence occurrences, such as accidents or serious incidents. High-consequence indicators are sometimes referred to as reactive indicators

Lower-consequence indicators. Safety performance indicators pertaining to the monitoring and measurement of lower-consequence occurrences, events or activities such as incidents, non-conformance findings or deviations. Lower-consequence indicators are sometimes referred to as proactive/predictive indicators.

Metrics. Metrics are indicators that an AMO has identified to have contribution to its safety performance.

8. INTRODUCTION.

8.1 SAR-145.64 requires a SAR-145 AMO (except a SAR-145 Subpart D organisation) to establish an SMS acceptable to the Authority.

8.2 The SMS that the AMO establishes has to commensurate with the size of the AMO and the complexity of its aviation services. Safety performance monitoring and measurement is an element in the required SMS framework.

8.3 CAAS AC 1-3 provides broad guidance to the aviation industry on the implementation of an SMS, including the setting of safety performance indicators (SPI) and targets (SPT) to provide measurable ways of ensuring and demonstrating the effectiveness of SMS beyond regulatory compliance. These indicators and targets established by an AMO have to be agreed with CAAS.

8.4 The aviation-related maintenance sector is diverse in its aviation services and operations, and ranges from aircraft maintenance to component overhaul and part repair works. To allow for meaningful comparison and benchmarking within a diverse aviation-related maintenance sector, it is necessary to provide guidance on the approach and methodology in setting the SPIs.

8.5 This AC contains a framework that aims to provide guidance and consistency in the methodology to establish, monitor and review SPIs, accounting for the size, complexity and location of an organisation.

9. FRAMEWORK FOR ESTABLISHING SPIs

9.1 The framework for establishing the SPIs for AMOs consists of:

i. **Grouping.** The AMOs are grouped according to the complexity of their aviation services. Please see paragraph 10 for more details.
ii. **Identification of appropriate SPIs**. Each AMO is to identify 3 basic SPIs. These are the 'outcome' SPIs that provide objective evidence on the effectiveness of an AMO's SMS. Each AMO would use these indicators to monitor and set its safety performance targets during the periodic safety performance review. Please see paragraph 11 for more details.
iii. **Safety Performance Review.** Each AMO is to identify and agree appropriate metrics with CAAS during the periodic safety performance reviews. Please see paragraph 13 for more details.

10. THE THREE GROUPS OF AMOs

10.1 For the purpose of setting the SPIs in the aviation-related maintenance sector, the AMOs would be classified into:

i. Aircraft Maintenance group
ii. Component Overhaul group
iii. Part Repair group

10.2 These groups are differentiated according to the complexities of their aviation services and operations for the SMS implementation. For the ease of reference, CAAS generally uses the organisational approval class as contained in SAR-145 Section 2 Appendix 1 to determine which group an AMO belongs to:

Generally holds the Approval Class SAR-145 Section 2 Appendix 1	Identified group as described in this AC	Primary scope of work	Remarks
Aircraft (A1 – A3 Ratings)	Aircraft Maintenance group	Maintain aircraft	AMO may have separate line and base maintenance sub-groups
Engines (B1 – B3 Ratings)	Component Overhaul group	Engine disassembly, assembly and / or test in test cell	AMO may have part repair/rebuild work, which supports its core business in overhaul of engines
Components, other than complete engines or APUs (C1 – C20 Ratings)		Component (mechanical / avionics / electrical) / engine module disassembly, assembly and / or test on test-bench	AMO may have part repair/rebuild work, which supports its core business in overhaul of components
Components, other than complete engines or APU (C1 – C20 Ratings)	Part Repair group	Part clean, inspect, repair/rebuild and final inspect	AMO's main business is in applying specialized processes and proprietary techniques to rework/rebuild unserviceable parts
Specialized services (D1 – D2 Ratings)		Part repair/rebuild and / or inspect	AMO's main business is in providing specialized processes and treatments on parts from other AMOs

10.3 Large and complex AMO may carry out maintenance in two or all groups. In such case, CAAS will discuss with the AMO and agree on the grouping(s).

11. THE THREE BASIC SPIs FOR EACH GROUP

11.1 ICAO Doc 9859 suggests that a range of high-consequence as well as lower-consequence SPIs provide a more comprehensive insight into the service provider's safety performance.

11.2 For each of the SPI that an AMO selected, the object of the measurement (or event) has to occur sufficiently frequent that a trend can be established and targets and alert set. An indicator that is zero most of the time is not amenable to trending and setting of targets. Empirically, repeated events may be very low for an AMO and therefore event rate is not a suitable SPI for the AMO sector.

11.3 CAAS recommends that AMO establish their basic SPIs on events in categories defined by the event's severity dimension. A common set based on three severity levels is recommended. This allows for meaningful comparison and benchmarking.

11.4 There are three Severity Levels of events, and are categorized according to the following principles:

- Severity Level One: Aircraft system failure that caused immediate abortion of the flight operation. Component / part that did not conform to approved data and resulted in a recall. Continued operation of the aircraft, component(s) or part(s) was not allowed.

- Severity Level Two: Aircraft system failure that lowered the safety margin of the aircraft essential flight systems. Component / part that did not conform to approved data and the safety margin of the component / part was lowered. Continued operation of aircraft / released component(s) / released part(s) was allowed but

restricted.

- Severity Level Three: Aircraft system, component or part discrepancies / failures were identified and corrected without affecting the operation of the aircraft system or affecting any other component(s) or part(s) that had been released.

11.5 The AMO has to determine the Severity Level of each event at the end of its investigation. Investigation to an event could be triggered by warranty claim, customer complaint, maintenance related air-turn-back or damage to aircraft / aircraft system. **Appendix 1** elaborates on the principles and provides examples of severity of events for each of the three groups of AMOs.

11.6 Events should not be limited to those on products and articles that are used on Singapore registered aircraft. SPIs measure and monitor the safety performance of the SMS that the AMO has implemented for all of its aviation services and products.

11.7 However part/component turn-backs, reworks and quality control pick-ups that occurred on the work-in-progress products / services are not considered as events for the basic SPIs. These quality issues are addressed by quality assurance or quality control programmes. They have strong correlations with the three basic SPIs and are treated as metrics together with other measurements that serve the same purpose. Paragraph 13 contains guidance on selecting metrics.

11.8 SPIs are expressed as event occurrence rates rather than absolute numbers and are tracked on charts. The AMO has to sum up the numbers of all the categorised event occurrences for a specific time interval and divide the numbers by the man-hour utilized during the same time period. The AMO would chart out the results of these basic SPIs for a particular period. In some cases, the SPI may be divided by the flight departures as in the case for AMOs that are performing line maintenance services.

11.9 For example in a mid-size workshop that overhauls mechanical components, it computed its man-hours over the 3 month period is 16970 man-hours. Over the same 3 months, it received 6 components back from its customers. Investigation showed that all 6 components had not been overhauled to their Component Maintenance Manual requirements.

a) Two components, (Component A and B) failed and had caused the shut-down of the critical system and grounding of an aircraft,
b) Two components (Component C and D) had failed prematurely on wing and
c) Two components (Component E and F) had external damages and discrepancy.

Analysis of the failure causes and consequences of Component A concluded that there is a systemic problem that needs immediate correction and recalling of all Component As that were released to other customers. This event is classified as Severity Level 1 event.

Analysis of failure causes and consequences of Component C concluded that there is a systemic problem, but the consequence is not severe enough to recall all the Component Cs immediately. Engineering assessed that the delivered Component Cs can continue to operate on wing and a dispensation is issued for the discrepancy. These event is classified as Severity Level 2 event.

Analysis of failure causes and consequences of Components B, D, E and F concluded that the cause of the failure are contained and unique to these failed components. These components are made serviceable again by the AMO. These four events are classified as Severity Level 3 events.

The SPIs for the three months in the example are:
a) Severity Level 1 rate: 1 / 1.697 = 0.59 per 10000 hrs
b) Severity Level 2 rate: 1 / 1.697 = 0.59 per 10000 hrs
c) Severity Level 3 rate: 4 / 1.697 = 2.35 per 10000 hrs

11.10 An AMO that is located outside of Singapore may establish SPIs that are agreed with its local State Aviation Authority. In such case, CAAS may accept these SPIs provided that

they are based on the principles and guidance as contained in ICAO Safety Management Manual (Doc 9859).

11.11 CAAS may request AMOs for additional SPIs after reviewing the safety performance of the sector.

12. SAFETY PERFORMANCE MONITORING - SPI TREND, ALERT AND TARGET

12.1 ICAO in its Annex 19 defines safety performance as a service provider's safety achievement as defined by its safety performance targets and safety performance indicators.

12.2 The AMO has to monitor their SPIs, including the basic SPIs, by using charts that identify their trends. These charts may have monthly, quarterly, bi-annually data points. The data point interval has to enable the data to be graphical trended for target setting.

12.3 By looking at trends, the AMO should be able to identify any abnormality and to investigate and address the abnormalities. The AMO should also be able to set improvement targets (SPT) based on the historical trend.

12.4 As the target (SPT) defines the long term achievement that an organisation intends to achieve for an SPI, the AMO should set a realistic and achievable SPT.

12.5 The AMO has to set SPTs for the three basic SPIs mentioned in paragraph 11. It can be set using historical data if that is available or by using the AMO's expert knowledge.

12.6 Besides setting SPIs and SPTs, the AMO should also establish alerts in the SPI chart to define the abnormal/ unacceptable events occurrence rates. The alert level setting will effectively serve as the demarcation line between the acceptable trending region and the unacceptable region for a safety indicator. So long as the events occurrence rate for an indicator does not trend beyond or breach the set alert level criteria, the performance is deemed to be acceptable and is achieving the SPT.

13. SAFETY PERFORMANCE REVIEW AND SELECTION OF METRICS

13.1 CAAS will periodically review the safety performance of its AMOs. The review period will coincide with the AMO's approval renewal interval for the sole purpose of expediency. The intent of the review is to ensure that the SPIs and SPTs remain relevant and appropriate, or if otherwise to change or revised them.

13.2 Before the review by CAAS, the AMO should have assessed its safety performance and have prepared the necessary information and proposal it plans to discussed with CAAS. Such information and proposal should be provided to CAAS at least one month prior to the approval renewal audit / inspection.

13.3 In the review, CAAS may also consider other metrics that monitor key outputs and inputs of management and operational processes. Metrics that are related to the workplace conditions may also be identified for monitoring. Although CAAS adapted the ICAO SHELL Model as contained in ICAO Circular 216-AN31, as the model in this AC to identify workplace conditions, an AMO may use other human factor analysis models.

13.4 An AMO may use the following steps during the safety performance review:

1) Review of safety performance targets SPTs and setting new SPTs

The trends of the basic SPIs are analysed and assessed if the target that has been set is achievable. The AMO may propose revising the SPT when the trend of SPI showed that the agreed SPT would have been achieved before the agreed target date for achievement. If the SPI is trending towards an SPT that is not achievable by the agreed date, the SPT may be revised either to a later target achievement date or lower target to achieve.

2) Review of events and identifying metrics for monitoring

The events that happened in the past year are reviewed. The workplace conditions that led to the events can be identified. The workplace conditions could be related to the organisation of the workplace, the hazards that are inherent at the workplace or the conditions of the operational staff. The AMO may then identify the metrics relevant to the conditions and set targets to achieve. A list of common conditions and their related metrics is provided in **Appendix 2**.

3) Metrics for monitoring organisational and management processes

Hazards and workplace conditions are direct results of the AMO's organisational and management decisions and processes. When the AMO recognised that these processes had led to events, the related metrics can be identified. Some metrics are basic, for example SMS implementation and QMS metrics. A list of possible metrics is provided in **Appendix 2**.

13.5 The list contained in **Appendix 2** is not exhaustive. It provides the AMO with some examples to start its process of identifying metrics.

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APPENDIX 1: SEVERITY LEVEL TABLE FOR AMO SECTOR

Group	Severity					
	Level One		Level Two		Level Three	
	Definition	**Examples**	**Definition**	**Examples**	**Definition**	**Examples**
Aircraft Maintenance	Failure in aircraft system that required immediate abortion of aircraft operation. Serious injury to occupants, cabin crew	Specific events such as when system is forced to shut-down to prevent further damage. Case where diversion, air turn back, or rejected take off is needed	Failure in aircraft system/hardware that reduced aircraft's system redundancy and operational capability and performance. Aircraft operating in an abnormal adverse condition is affected	Maintenance errors resulting in pre-mature failure of aircraft system / hardware that resulted in application of Cat A (time/cycle), Cat 'B' (3 day) & Cat 'C' (10 day) MEL to continue operating	Aircraft servicing and maintenance errors discovered during aircraft operation that do not affect flight operation or aircraft flight systems	Incorrect procedures and hardware used in maintenance, e.g. wrong fastener, FOD in compartment, over/under-servicing etc requiring AMO to correct. Customer pick-ups during hand-over of aircraft, pilot pick-ups before accepting aircraft.
Component Overhaul	Alert issued on engine or component that required immediate attention. Engine or component failure in service that required crew to shut down engine/system	Engine/component released with un-approved parts, maintenance discrepancies that potentially can damage the aircraft or system, triggering an immediate alert to the air operators	Time based recall of engine/component/parts for rework.	Engine / component released with un-approved parts, maintenance discrepancies that affect the aircraft system performance. Design office approval is required for continued operating with the discrepancy	Engine / component returned with maintenance related defect(s)	Warranty on returned engine/component that needs re-work, e.g. replacement of parts, correcting defect etc
Part Repair	Alert issued on repaired part that had caused air operation immediate attention and in-opt of engine/system	Maintenance discrepancies affecting the material properties, e.g. heat treatment, chemical treatment, coating strength, triggering an immediate alert to the air operators	Time based recall of parts for rework	Maintenance discrepancies affecting the material properties, e.g. heat treatment, chemical treatment, coating strength Design office approval is required for further continued operating with discrepancy	Parts returned with repair related defect(s)	Warranty on returned part that needs re-work, e.g. re-coating, trimming of edges, cleaning, removing of excess coatings etc

APPENDIX 2: EXAMPLES OF ORGANISATIONAL, MANAGEMENT AND WORKPLACE CONDITIONS METRICS

Organisational and Management Metrics		
SMS Implementation	**Quality Management System**	**Organisational Management Processes**
Voluntary Reporting Rate	Regulatory Audit Finding Severity / Rate	Operational Staff Competency Measurement
Human Error Rate	Number of Internal Audit	Operational Staff Recruitment Process Measurement
Internal Quality Escape Rate	Customer Satisfaction Index	Supervisor/Operational Staff Ratio
Safety Culture Index	Warranty Rate	
Number of Safety Review		
Number of Safety Audit		
SMS Training - Frequency		
Number of Staff Trained on SRM and Investigation		
Investigation Completion Rate		

Workplace Condition Factors (and Metrics)		
Workplace Organisation	**Workplace Hazards**	**Operational Staff Conditions**
Time Pressure Factor – Metrics - overtime rate or man-hour slack trend	Environment – Physical Factor Metric – work area safety studies	Liveware Internal – Psychological Factors such experience, knowledge, training of the staff Metric – operational staff experience level on task
Staff Work Exposure Factor – Metrics - staff/product ratio, or staff turn-over trend	Environment – Facilities Factor Metric – maintenance budget	Liveware Internal – Physiological Factors such as health, fatigue of staff Metric – sick leave trend
Staff Communication Factor – Metric - communication effectiveness or frequency	Hardware – Equipment and Tools Factor Metric – measurement on availability and serviceability	
Work Allocation Factor – Metric – measurement on balance of work distribution	Hardware – Aircraft / Component / Part Factor, Metric – measurement related to complexity of aircraft system / component / part in operations	
Supervision Factor – Metrics – engineer / mechanic ratio or cell leader / operator ratio	Hardware – Spares and Materials Factor Metric – measurement on spares and materials not compatible with the work assigned	
Work Load Factor – Metric – non-routine hours trend	Software – Procedures for the Task Factor Metric – number of inadequate procedures for a task	
	Liveware External – Time Pressure Factor Metric - on-time-delivery rate	
	Liveware External – Communication Factor, Metric – measurement on operational personnel communication skills with other	
	Liveware External – Workplace Culture Factor, Metric – supervisor's communication programmes with its operational personnel	
	Liveware External – Team Relationship Factor, Metric – measurement on team dynamics	