

# **Metrolinx FRACAS (Failure Reporting, Analysis, and Corrective Action System) Process**

RAMS-1

Revision 0

Date: 28/07/2020

# **FRACAS (Failure Reporting, Analysis, and Corrective Action System) Process RAMS-1**

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# Preface

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This is the first edition of the FRACAS (Failure Reporting, Analysis, and Corrective Action System) process published as part of Metrolinx RAMS (Reliability, Availability, Maintainability and Safety) Standards. It describes a closed loop continuous improvement system where failures and faults are formally reported, analysis is performed to the extent that the failure cause is understood, and positive corrective actions are identified, implemented, and verified to prevent further recurrence.

The purpose of Metrolinx RAMS Standards is to formalize the framework to adequately manage RAMS performance of all Metrolinx assets for the entire life cycle starting from concept, through risk assessments, stage gate approvals, design and specifications, construction, systems integration, validation, acceptance, operation, maintenance, performance monitoring and decommissioning. Metrolinx RAMS standards, which are built as an adaptation of European Standard EN 50126-1:2017, provide internal Metrolinx staff and external stakeholders involved in design, construction, operation and maintenance of Metrolinx assets with a common understanding and a systematic process for RAMS management. Ultimately, they provide a systematic approach for specifying RAMS requirements and demonstrating that these requirements are achieved.

This document was developed by the Engineering Reliability and Performance Office, Engineering and Asset Management Division, Capital Projects Group, Metrolinx.

Suggestions for revision or improvements can be sent to the Metrolinx Engineering Reliability and Performance office, Attention: Director of Engineering Reliability and Performance who shall introduce the proposed changes to the Metrolinx Engineering Reliability and Performance office. The Director of the Engineering Reliability and Performance office ultimately authorizes the changes. Be sure to include a description of the proposed change, background of the application and any other useful rationale or justification. Be sure to include your name, company affiliation (if applicable), e-mail address, and phone number.

July 2020

## Amendment Record

Revision	Date (DD/MM/YYYY)	Description of changes

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# Documents

TABLE 0-1 SUPPORTING DOCUMENTS

Document Number	Document Title	Relation
BS EN 50126-1:2017	Railway Applications - The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS) (PHASE 1: Adoption of European Standard EN 50126-1:2017)	Parent Standard
CKH-ASMT-PRC-001	Asset Data and Information Standards	Reference
CKH-ENG-FRM-008	Standards Deviation Request Form	Reference
CKH-ENG-PRC-001	Procedure for Requesting Deviations to Metrolinx Standard Technical Requirements	Reference
CKH-RISK-PLN-006	RAMS Program	Reference
CPG-QAT-FRM-106	CPG Terms Glossary	Reference
MIL-STD-2155	Failure Reporting, Analysis, and Corrective Action System	Reference
MIL-STD-721	Definitions of Terms for Reliability and Maintainability	Reference
RAMS-2	FMECA Process	Related Process
RAMS-4	RCA Process	Related Process
TBD	Roles and Responsibilities Matrix (RACI) for RAMS tasks	Document

# Acronyms and Abbreviations

TABLE 0-2 ACRONYMS AND ABBREVIATIONS

Acronym	Full Name
CARB	Corrective Action Review Board
CPG	Capital Projects Group
CLOS	Customer Level of Service
CSAT	Customer Satisfaction
FMECA	Failure Mode, Effects, and Criticality Analysis
FRACAS	Failure Reporting, Analysis, and Corrective Action System
FRB	Failure Review Board
IP	Investment Panel
MDT	Mean Down Time
MTBF*	Mean Time* Between Failures
MTBM*	Mean Time* Between Maintenance
MTTF*	Mean Time* To Failure
MTTR	Mean Time to Restore
MUT	Mean Up Time
NFF	No Fault Found
OTP	On-Time Performance
RAM	Reliability, Availability and Maintainability
RAMS	Reliability, Availability, Maintainability and Safety
RCA	Root Cause Analysis

**\*Note:** "T" and "Time" may be substituted for other utilization measures as appropriate (i.e. Mean Distance Between Failures as MDBF, etc.).

# Definitions

TABLE 0-3 DEFINITIONS

Term	Definition	Source
Accident	Has the meaning given in the Canadian CMREA Standard	Canadian Common Method for Risk Evaluation and Assessment (CMREA)
Asset	Any physical or tangible item that has potential or actual value to Metrolinx (excluding intellectual property, inventory to be sold, human resources, and financial instruments), as well as IT systems and software.	CKH-ASMT-PRC-001 Note: refer to CKH-ASMT-PRC-001 Asset Data and Information Standards for additional asset-related definitions.
Asset Class Teams	Metrolinx business units who have been designated as being accountable for the completeness and accuracy of information about a given class of assets.	CKH-ASMT-PRC-001
Asset Hierarchy	Hierarchical grouping of Metrolinx assets, organized within parent-child relationships.	CKH-ASMT-PRC-001
Availability	Ability of an item to be in a state to perform a required function under given conditions at a given instant of time or over a given time interval, assuming that the required external resources are provide.	BS EN 50126-1:2017
Corrective Action	A documented design, process, procedure, or materials change implemented and validated to correct the cause of failure or design deficiency. Note: corrective actions are sometimes distinguished from preventive actions and referred to collectively as CAPA (i.e. for Root Cause Analysis), however the FRACAS process uses the term corrective action in reference to both corrective and preventive actions	MIL-STD-721, with note added
Corrective maintenance	Maintenance carried out after fault detection to effect restoration	BS EN 50126-1:2017
Downtime	The time (in seconds or hours), an asset or system is not fully functional or operational (e.g. degraded mode where only limited functionality is available, or is down with no functionality). There may be a variety of reasons for downtime, including but not limited to: Preventative Maintenance, Corrective Maintenance, etc.	Adapted from PRESTO Glossary of Terms - 2018



Error	Discrepancy between a computed, observed or measured value or condition and the true, specified or theoretically correct value or condition	BS EN 50126-1:2017
Failure	[1 ] Loss of ability to perform as required  [2] The event, or inoperable state, in which any item or part of an item does not, or would not, perform as previously specified	[1] BS EN 50126-1:2017  [2] MIL-STD-721
Failure Mode	[1] manner in which failure occurs  [2] The manner by which a failure is observed. Generally describes the way the failure occurs and its effect on equipment operation.	[1] BS EN 50126-1:2017  [2] MIL-STD-1629 Rev A
Failure rate	Limit of the ratio of the conditional probability that the instant of time, T, of a failure of a product falls within a given time interval (t, t + Δt) and the duration of this interval, Δt, when Δt tends towards zero, given that the item is in an up state at the start of the time interval Note: For applications where distance travelled or number of cycles of operation is more relevant than time, then the unit of time can be replaced by the unit of distance or cycles, as appropriate	BS EN 50126-1:2017
Failure Review Board (FRB)	A group consisting of representatives from appropriate asset class team representatives with the level of responsibility and authority to assure that failure causes are identified and corrective actions are taken.	Adapted from MIL-STD-2155
Fault	Abnormal condition that could lead to an error in a system	BS EN 50126-1:2017
Function	Specified action or activity which can be performed by technical means and/or human beings and has a defined output in response to a defined input	BS EN 50126-1:2017
Incident	Has the meaning given in the Canadian CMREA Standard	Canadian Common Method for Risk Evaluation and Assessment (CMREA)
Investment Panel (Metrolinx)	The Investment Panel ("IP") is management's ultimate accountable governance body for benefits management of business cases across the entire capital project lifecycle	Investment Panel ToR (03-1-2019)
Maintainability	Ability to be retained in, or restored to, a state to perform as required, under given conditions of use and maintenance	BS EN 50126-1:2017

Maintenance	Combination of all technical and management actions intended to retain an item in, or restore it to, a state in which it can perform as required	BS EN 50126-1:2017
Preventive maintenance	Maintenance carried out to mitigate degradation and reduce the probability of failure	BS EN 50126-1:2017
Reliability	Ability to perform as required, without failure, for a given time interval, under given conditions	BS EN 50126-1:2017
Reliability growth	Iterative process for reliability improvement	BS EN 50126-1:2017
Repair	Direct action taken to effect restoration	BS EN 50126-1:2017
Restoration	Bringing an item into a state where it regains the ability to perform its required function after a fault	BS EN 50126-1:2017
Ridership	The number of persons who ride a system of public transportation to travel between two end points	N/A
Service Interruption	A service interruption is any failure resulting in the inability to provide a service to the normal standard (i.e. unplanned schedule changes, train/bus delays and cancellations. customer-facing device unavailable, etc.)	N/A
Subsystem	Part of a system, which is itself a system	BS EN 50126-1:2017
System	Set of interrelated elements considered in a defined context as a whole and separated from their environment	BS EN 50126-1:2017
Utilization	The measure of the time, or other appropriate parameter such as cycles, ridership, miles, loads, trips, etc. that the asset is in active operation	N/A

For additional terms and definitions, please refer to the *CPG Terms Glossary* (refer to *CPG-QAT-FRM-106, CPG Terms Glossary*, for more details).

# 1. Overview

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## 1.1 Purpose

- 1.1.1 The purpose of the FRACAS process is to provide standard reliability and performance reporting and monitoring across Metrolinx assets in order to:
- a) Ensure that compliance with well-defined reliability, availability, maintainability, & safety (RAMS) and customer level of service (CLOS) requirements at all levels is maintained through periodic score-carding;
  - b) Guide failure data collection process for effective reporting and root cause analysis;
  - c) Provide prioritization for analysis and efforts in correcting failures;
  - d) Monitor and validate the efficiency of corrective actions implemented following root cause analysis; and
  - e) Facilitate life cycle cost estimations for optimized maintenance strategies and asset life
- 1.1.2 The FRACAS process is a closed-loop system in which failures and faults are formally reported, analysis is performed to the extent that the failure cause is understood, and positive corrective actions are identified, implemented, and validated to prevent further recurrence of the failure.
- 1.1.3 FRACAS data and reports shall be periodically reviewed to determine whether any improvement is needed in operation and maintenance procedures and manuals, system training documentation, system design, and human factors aspects of operation and maintenance.

## 1.2 Scope

- 1.2.1 The FRACAS process only applies to Metrolinx assets in the operation, maintenance, and performance monitoring life cycle phase [Figure 1-1]. It is a process for reporting, analyzing and correcting actual asset or system failures and does not apply to theoretical or potential failures.
- 1.2.2 The FRACAS process shall be maintained throughout the operation, maintenance, and performance monitoring life cycle phase for all Metrolinx assets [Figure 1-1]. To ensure that priority issues are addressed, the failures and faults should be categorized for both safety and reliability for varying levels of severity/criticality (i.e. accident, incident, service-interrupting, non-service interrupting, etc.). All the data collected and analyzed, which is referred to as FRACAS Data, as well as corrective actions implemented through the FRACAS process, shall be compiled into the FRACAS Report, which shall be published and reviewed periodically (at least once per month) as summarized in Figure 1-2 below, and detailed in Section 4 of this process document.

Figure 1-1 The interrelation of RAMS management process and system life cycle - the V-Cycle representation  
 [Source: BS EN 50126-1:2017]

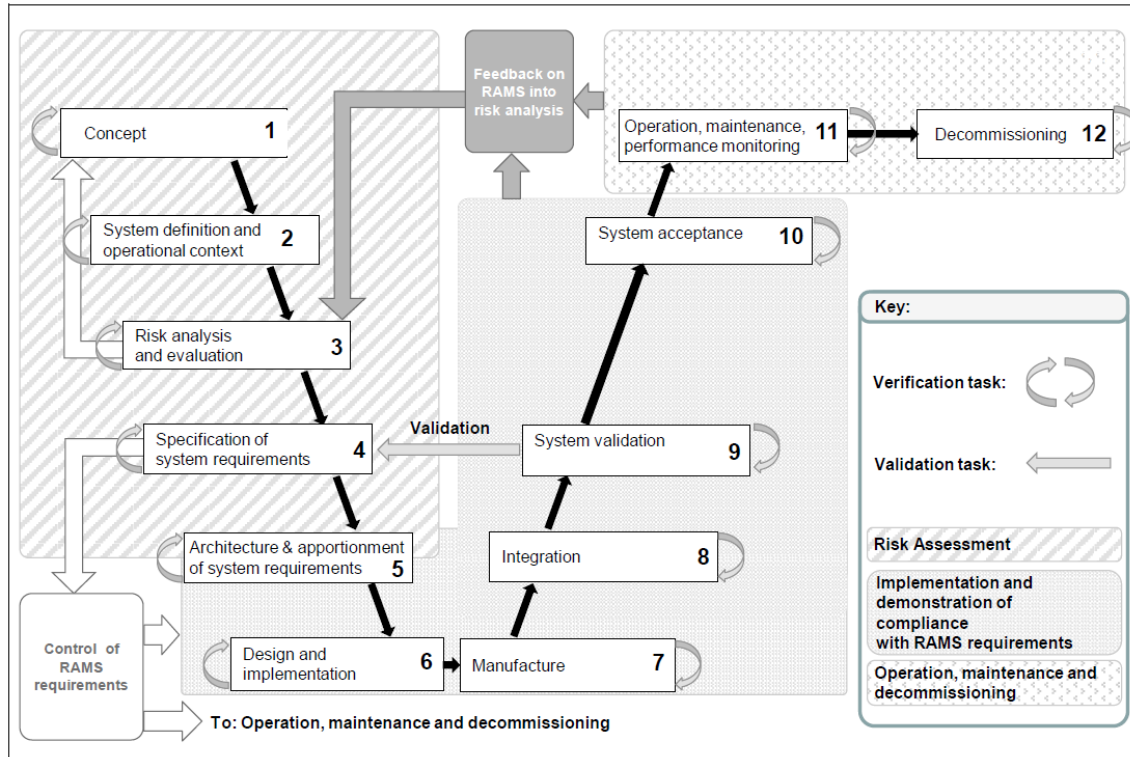
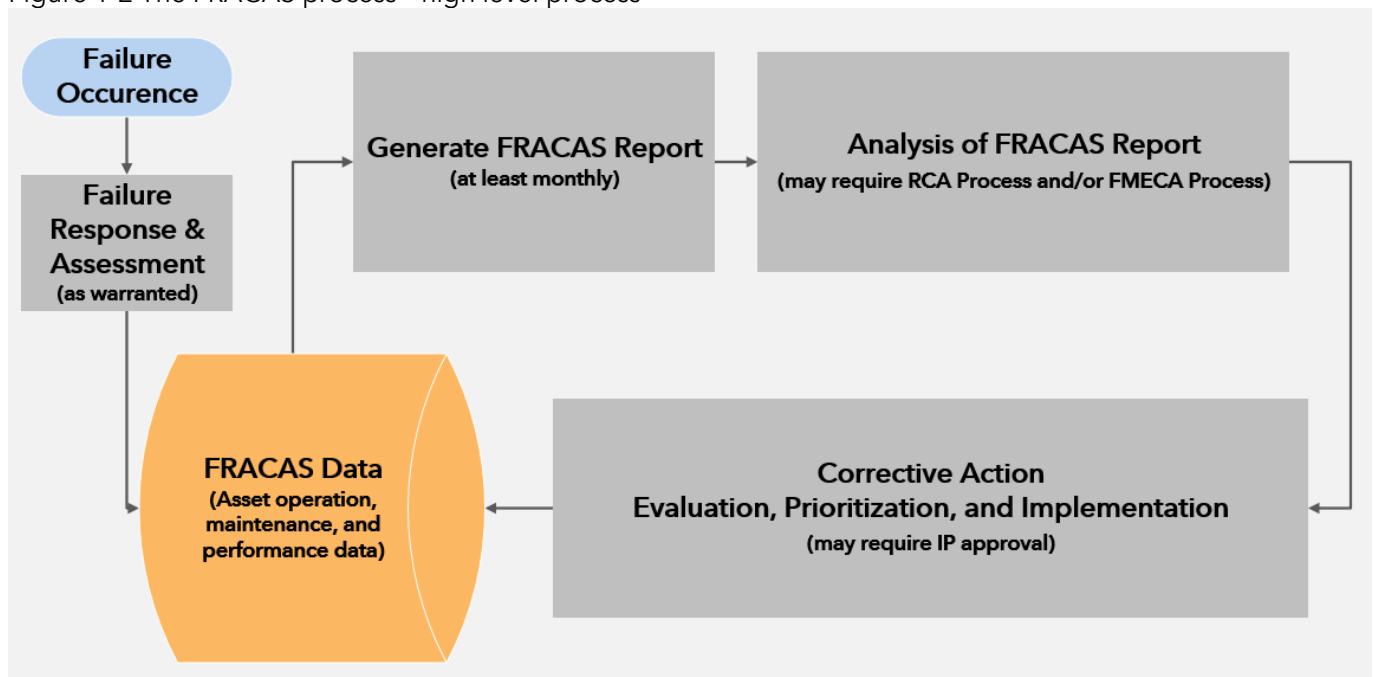


Figure 1-2 The FRACAS process - high level process



- 1.2.3 The minimum FRACAS Data required to produce a FRACAS Report is information about faults and failures identified during operation and maintenance [detailed in Section 2.1]
- 1.2.4 FRACAS data should also include additional information to provide context to the faults and failures for reliability, availability, maintainability, and safety analysis. These other FRACAS data types include, but are not limited to:
  - a) Utilization data [detailed in Section 2.2]
  - b) Maintenance Data [detailed in Section 2.3]
  - c) CLOS and RAMS Targets [detailed in Section 2.5]
  - d) Industry Benchmarking [detailed in Section 2.5]
  - e) Corrective actions implemented and proposed to achieve CLOS and RAMS targets [detailed in Section 2.4]
- 1.2.5 FRACAS Reports shall be produced on a regular basis, where the regular reporting period and data lag shall be defined by each asset class team, and shall not be less than one report per month, but may be more frequent depending on the individual needs and preferences of each asset class team.
- 1.2.6 The FRACAS Report shall include four parts at a minimum for every asset class team, as summarized below. Asset class teams may define additional parts individually, but any deviation or deletion of the four parts specified below shall require approval from the Metrolinx RAMS team through the Standards Deviation Request Form [CKH-ENG-FRM-008].
  - a) PART 1: Corrective Actions Monitoring [detailed in Section 3.1]
  - b) PART 2: Asset CLOS Performance [detailed in Section 3.2]
  - c) PART 3: Asset RAM Performance [detailed in Section 3.3]
  - d) PART 4: Asset Maintenance Efficiency [detailed in Section 3.4]
- 1.2.7 The FRACAS Report shall be reviewed and analyzed on a regular basis, where the regular review period is to be defined by each asset class team, and shall not be less than once per month, but may be more frequent depending on the individual needs and preferences of each asset class team. The purpose of this review and analysis is to identify opportunities to improve asset reliability and performance to achieve or exceed RAMS and CLOS targets, as well as to monitor the effectivity of implemented corrective actions relative to expected impact.
- 1.2.8 There are several types of activities which should take place to support the regular failure data and FRACAS Report review requirements, each of which provides its own function, and include but are not limited to:
  - a) Failure Review Board (FRB): The FRB should meet on a regular basis to review FRACAS failure data and FRACAS Reports, initiate and monitor ongoing investigations and analyses (i.e. RCA) as required, and monitor the effect(s) of implemented corrective actions.
  - b) CLOS Huddle Meetings: The purpose of the CLOS Huddle meetings (i.e. Rail OTP Huddle, CSAT Huddle, etc.) are to understand the failure causes & trends and to monitor corrective actions as they apply to the CLOS target under review (i.e. rail service-interrupting failures and rail OTP).

- c) Corrective Action Review Board (CARB): The purpose of these meetings is to evaluate, select, and document the appropriate corrective action(s) to be recommended for implementation. The possible corrective actions for evaluation should be provided by the FRB from their investigations and analyses, and corrective actions recommended for implementation by the CARB should then return to the FRB for monitoring the effect(s). The CARB may need to take recommended corrective actions to the Investment Panel (IP) prior to implementation and monitoring by the FRB.

## 1.3 Key Responsibilities

- 1.3.1 The RAMS team owns this process document and is responsible for ensuring this process meets or exceeds industry standards and applicable regulations as well as ensuring that asset class teams comply with this process.
- 1.3.2 The asset class teams are responsible for defining the input data systems and auditing the input data content required to comply with the FRACAS process [detailed in Section 2].
- 1.3.3 The asset class teams are responsible for showing compliance with the FRACAS process through regular FRACAS reporting as detailed in this process document [detailed in Section 3].

**Note:** This process is not specific to any contract type. For detailed responsibilities based on different contract types, refer to RAMS RACI document.

## 2. FRACAS Data Minimum Requirements

### 2.1 Failure Data

2.1.1 The failure data shall include the following information at a minimum for the purposes of the FRACAS process:

- a) Work order identification
- b) Date of failure discovery
- c) Asset identification through to lowest level of the applicable functional asset hierarchy (i.e. system, position, asset, etc.)
- d) Problem description: identifies the general problem with a piece of equipment (i.e. leaking, seized, vibration, etc.)
- e) Failure description: defines the specific component that failed and the type of failure (i.e. shaft bent, bearing worn, gasket leaking, etc.) and introduces more granularity into failure reporting, allowing the maintenance department to analyze equipment failures with greater detail
- f) Cause description: identifies the general reason why the asset was underperforming (i.e. operator error)
- g) Remediating Action description: identifies the action that the maintenance technician took to rectify the equipment issue (cleaned, replaced, etc.)
- h) Service-interrupting failure (i.e. yes/no)

2.1.2 The failure data should also include the following information as available:

- a) Safety level ranking of failure: qualifies the degree to which the failure impacted the safe operation of the asset
- b) Reliability level ranking of failure: qualifies the degree to which the failure impacted the reliable operation of the asset
- c) Time of failure discovery
- d) Source of failure discovery identification (i.e. PM, Service Interruption Events logged in ServiceNow and L102, etc.)
- e) Source of failure discovery event identification (i.e. PM work order number, ServiceNow ticket number, L102 Event ID, etc.)
- f) Failure Confirmation Status (confirmed, no fault found, or unknown)
- g) Any other comments or notes as recorded by the technician(s) who worked to resolve the failure

### 2.2 Utilization Data

2.2.1 There are many different measures of utilization which may be applicable to different assets, systems, and components (i.e. calendar time, operational hours, operational cycles, number of trips, number of stops, mileage, loads, etc.)

- 2.2.2 The asset class teams shall define and document which utilization measure is applicable at all levels of each functional asset hierarchy for each asset class they own. Asset class teams shall also document the data source(s) for each utilization measure identified as well as any assumptions made and limitations identified.
- a) One example would be looking at the number of operated GO Train trips, which is available from two different data sources called "ATLS" and "CADAVAL" at a rail system, rail corridor, and station level, so which source should be used in which context(s) needs to be defined. Additionally, to calculate the utilization of a specific passenger cab car, an additional data source is needed to identify which trips included that specific cab car, and different systems and subsystems on the cab car may require additional or different utilization data sources to measure the usage.

## 2.3 Maintenance Data

- 2.3.1 There are two distinct types of maintenance data, Preventive Maintenance (PM) and Corrective Maintenance (CM) data.
- 2.3.2 The PM data shall include the following information at a minimum for the purposes of the FRACAS process:
- a) Work order identification
  - b) PM task identification
  - c) PM procedure reference
  - d) Asset identification (on which the PM maintenance was performed)
  - e) PM task scheduled interval
  - f) Date PM task was due to be performed by
  - g) Date PM task was actually performed
  - h) Total downtime to perform PM task
  - i) Total Labour hours to perform PM task
  - j) Details on materials and/or parts consumption
  - k) Details on inspection records (i.e. for tasks requiring voltage measurement, voltage values shall be recorded, etc.)
  - l) Description of faults or failures discovered and any corrective action performed
- 2.3.3 The CM data shall include the following information at a minimum for the purposes of FRACAS:

**Note:** CM data is highly linked to the Failure data, and may be stored as one table with the Failure Data as possible depending on the asset class team data systems.

- a) Work order identification
- b) Date and Time of failure discovery
- c) Date and Time of failure resolution
- d) Total Labour hours required to resolve failure
- e) Details on materials and/or parts consumption



## 2.4 Corrective Action Data

2.4.1 The corrective action data shall include the following information at a minimum:

- a) The date the corrective action was identified
- b) The date the corrective action was approved for implementation (if applicable)
- c) The date the corrective action was implemented (if applicable)
- d) The corrective action identification number (if implemented)
- e) Reference to the source of the corrective action (i.e. reference to a specific RCA)
- f) A description of the corrective action
- g) The RAM and/or CLOS measure(s) that are expected to be affected by the corrective action (for both positive and negative effects)
- h) A quantification of the expected effect(s) to each affected RAM and CLOS measure (for both positive and negative effects)
- i) Reference to the source(s) which documents the assumptions and justification for the quantification of the expected effect(s)
- j) The status of the corrective action which shall be one of the following:
  - 1) Specialist Recommended: which shall be used for corrective actions identified and deemed by the appropriate specialist(s) to be a viable solution to a known issue(s) and is therefore recommended for implementation to correct the issue(s).
  - 2) Team Approval: which shall be used for recommended corrective actions that have been identified by the asset class team as priority corrective actions, and are therefore under review by the asset class team for approval to be implemented.
  - 3) IP Approval: which shall be used for corrective actions which have been recommended by the asset class team for implementation, but also require Investment Panel (IP) approval before the corrective action can be implemented (i.e. funding required, etc.)
  - 4) Rejected: which shall be used for corrective actions which were not recommended for implementation either from being rejected by the asset class team or by the Investment Panel.
  - 5) Monitoring: which shall be used for corrective actions which have been implemented but where the full effect(s) have not yet been satisfactorily confirmed realized, and is being monitored as part of Part 1 of the FRACAS Report [detailed in Section 3.1]
  - 6) Complete: which shall be used for corrective actions which have been implemented and where the full effect(s) have been satisfactorily confirmed realized, therefore the corrective action is no longer being monitored as part of Part 1 of the FRACAS Report [detailed in Section 3.1]

## 2.5 CLOS Targets, RAMS Targets, and Industry Benchmarking Data

- 2.5.1 CLOS targets shall be provided by Metrolinx Senior Management team down to each asset class team. Asset class teams shall keep a record of each applicable target, the date the target was set, and the target value.
- 2.5.2 RAMS targets shall be kept as records by asset class teams including source and date of effectivity of the target. Possible sources for RAMS targets include asset class team distribution of CLOS target(s) down to lower levels of the functional asset hierarchies, contractual minimum performance requirements, supplier performance specification and guarantees, performance of similar systems, industry benchmarking data, etc.
- 2.5.3 Industry benchmarking data should be kept as records by asset class teams to be used as available to compare Metrolinx asset reliability and performance to the industry global standard performance. Industry benchmarking data for a specific system or asset is the operational data acquired from the users of the same system who operate under conditions comparable to Metrolinx. This data can be sourced through suppliers and manufacturers or directly from the users around the world with whom Metrolinx has an established relationship. Industry benchmarking data is key in identifying inherent design deficiencies that cannot be easily corrected by operational changes and should be corrected by supplier or manufacturer through system design upgrades.

## 3. The FRACAS Report

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### 3.1 PART 1: Corrective Actions Monitoring

- 3.1.1 The purpose of Part 1 of the FRACAS Report is to provide visibility on the implemented corrective actions and to monitor that each implemented corrective action is resulting in the expected effect(s), until the full effect has been satisfactorily observed in operation.
- 3.1.2 The input data required for Part 1 is:
- a) The data contained in the FRACAS Report Part 3 [detailed in Section 3.3] and Part 4 [detailed in Section 3.4] is required to understand the actual RAMS performance.
  - b) Corrective Action Data [detailed in Section 2.4] is required to understand how the actual RAMS performance compares to the expected effect(s) of the implemented corrective action(s).
- 3.1.3 Part 1 of the FRACAS Report shall be formatted as tables detailing each implemented corrective action, followed by relevant chart(s) graphically showing the effect(s) of each corrective action relative to expected effect(s). Additionally, each chart shall be followed by text providing context and summarizing the analysis of the corrective action trend monitoring.
- 3.1.4 The FRACAS Report Part 1 shall include the following information for each individual implemented corrective action:
- a) The first graphic shall be a table identifying and detailing the corrective action with the following fields:
    - 1) Corrective Action ID: is a unique identifier to track this corrective action and identifies the asset class team (ID), the Year of implementation, and a sequential number
    - 2) Corrective Action Description: describes the corrective action taken and what failure mode(s) the corrective action is expected to resolve.
    - 3) Implementation Date: is the date this corrective action was implemented in operation, and should be expressed as a date range if the corrective action implementation spans more than one month.
    - 4) Target(s) Impacted: lists the RAMS and CLOS targets impacted by this corrective action, with one row per impacted target.
    - 5) Expected Improvement: quantifies the expected effect the corrective action will have on each impacted target, with one row per impacted target.
    - 6) Trend Status: gives a high level overview of whether the corrective action actual effect is trending as expected
      - i. Green: Actual performance trending is better than or as expected (no additional action required)
      - ii. Yellow: Actual performance trending is at risk to fall below the expected effect (shall be monitored more frequently)

iii. Red: Actual performance trending is below the expected effect (shall be investigated)

b) The second graphic shall detail the actual performance by month and as a rolling average to compare to the projected performance based on the expected improvement. If multiple targets are impacted by a single corrective action, then there should be individual charts to monitor the effects on each individual target (i.e. for a corrective action expected to improve both OTP and CSAT performance).


**Note:** 12 Months is considered the standard rolling average measure, however longer or shorter time periods may be more appropriate to observe the mature performance, depending on the corrective action being monitored.

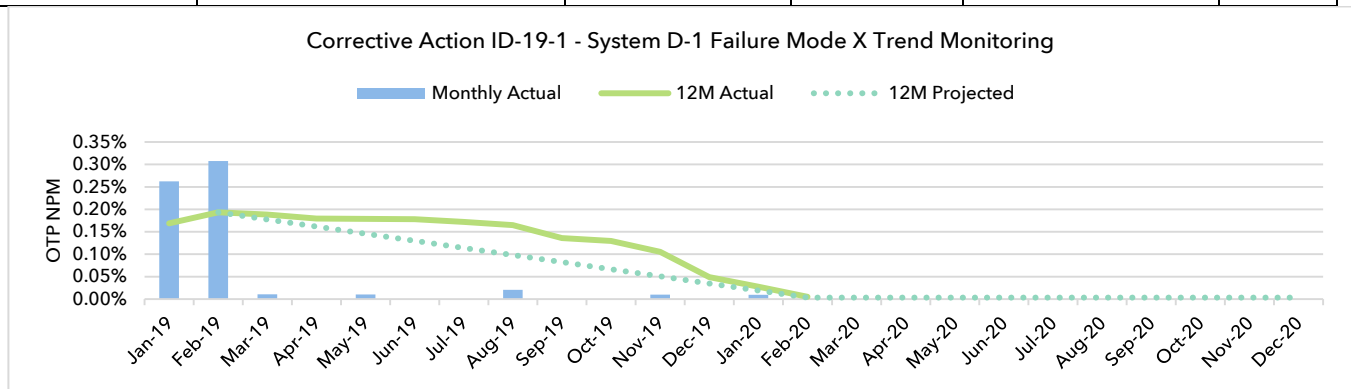
c) The third graphic shall be a text box detailing the analyst comments on the actual effect of the corrective action relative to the expected improvement, noting any additional analysis or action taken.

3.1.5 Implemented corrective actions shall be monitored as part of the FRACAS Report Part 1 until the full effect of the corrective action has been satisfactorily observed in operation. If a corrective action is not resulting in sufficient improvement in operation relative to expected effect(s) and associated RAMS and/or CLOS target(s), then additional action is required as detailed in section 0 "The FRACAS Process".

3.1.6 The below Figure 3-1 illustrates the formatting for an implemented corrective action in FRACAS Report Part 1. Figure 3-1 uses the example of the redesign of "System D-1" to eliminate a failure mode negatively impacting GO Train On Time Performance (OTP) Negative Performance Measure (NPM) as the implemented corrective action, with the mature performance measured based on a 12M rolling average.

Figure 3-1 FRACAS Report PART 1 - implemented corrective actions monitoring

Corrective Action ID	Corrective Action Description	Implementation Date	Target(s) Impacted	Expected Improvement	Trend Status
ID-19-1	Asset D System D-1 redesign to eliminate failure mode X	Feb-19	OTP NPM	0.19%	



**Analyst Comments:**

The single failure observed in January was investigated and confirmed to be a pre-mod unit. There was no occurrence of failure mode X in the last month, and overall the 12M Actual OTP is now trending On Track. This corrective action will continue to be monitored until June 2020 at the earliest to ensure no resurgence of failures.

## 3.2 PART 2: Asset CLOS Performance

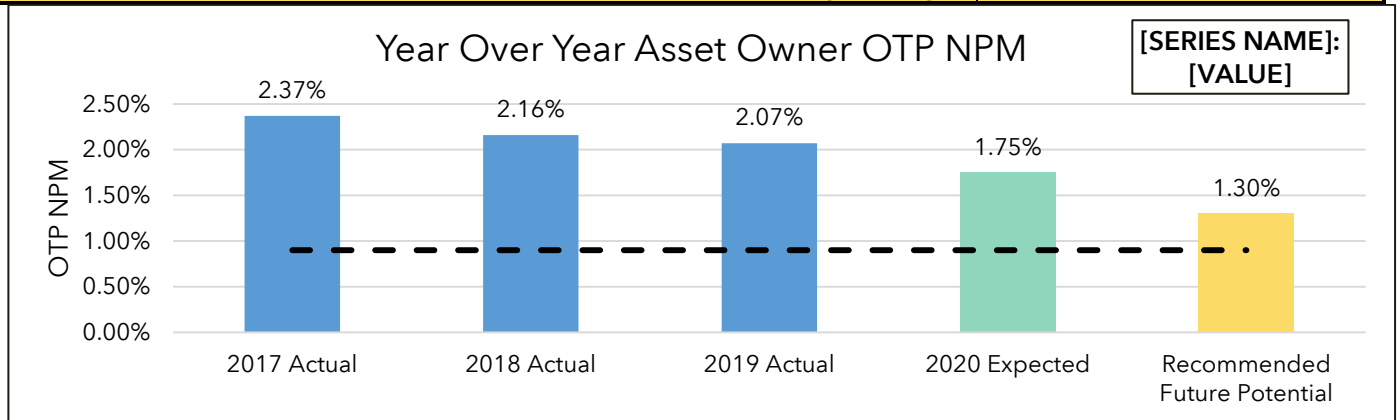
- 3.2.1 The purpose of Part 2 of the FRACAS Report is to provide regular score-carding of the actual asset performance in operation relative to the CLOS targets, such as on-time performance, customer satisfaction (CSAT), etc. to identify performance problems and provide direction for analysis and corrective action prioritization through trend monitoring.
- 3.2.2 The input data required for Part 2 is:
- a) The data contained in the FRACAS Report Part 1 [detailed in Section 3.1], Part 3 [detailed in Section 3.3], and Part 4 [detailed in Section 3.4] is required to understand the actual reliability and performance.
  - b) CLOS Target Data [detailed in Section 2.5] is required to understand how the actual reliability and performance compares to the company objectives. Sources of these targets include, but are not limited to, Asset Management Plans (AMP), company level key performance indicators (KPI), and Metrolinx strategic objectives (i.e. "strategic wheels").
- 3.2.3 Part 2 of the FRACAS Report shall consist of two parts:
- a) Part 2A shall be formatted as tables for each applicable CLOS target summarizing all implemented corrective actions from Part 1 as well as all recommended corrective actions not yet implemented. Additionally, each table shall be followed by a chart tracking the full history of the effects of implemented corrective actions on the actual performance relative to CLOS target since implementation of the FRACAS process for each asset class team.
  - b) Part 2B shall be formatted as charts at the CLOS targets level, with information through the functional asset hierarchies provided to support analysis as required and as available. Additionally, analyst comment shall be included in Part 2 of the FRACAS Report to provide context to the charts and summarize analysis performed and actions in work, as warranted.
- 3.2.4 The FRACAS Report Part 2A shall include the following information for each CLOS target applicable to the asset class team:
- a) The first graphic shall be a table identifying and detailing each corrective action with the following fields:
    - 1) The CLOS measure name and target value for the asset class team
    - 2) For historical corrective actions: the improvement expected and achieved for each year and the running total since the asset class team instituted the FRACAS process (or earlier if historical data is available)
    - 3) For implemented corrective actions being monitored (not yet fully achieved): details on the corrective action impact to the CLOS measure under review are repeated from PART 1 of the FRACAS Report [detailed in paragraph 3.1.4 a)], with the addition of the total expected impact of those corrective actions on the CLOS measure under review and resulting expected gap to the CLOS target.
    - 4) For recommended corrective actions not yet implemented: details including the date, source, and description of the recommended corrective action along with its expected potential impact to the CLOS measure under review, the status, and finally

the total expected impact of all recommended corrective actions on the CLOS measure under review and resulting expected gap to the CLOS target.

- b) The second graphic shall be a chart summarizing the annual actual performance relative to the CLOS target for historical corrective actions, implemented corrective actions being monitored, and recommended corrective actions to summarize the actual and expected performance relative to target and help prioritize recommended corrective actions to develop a plan to achieve the CLOS target (or improve further if the target has been achieved).
- c) The third graphic shall be a text box detailing the analyst comments on the actual effect of the corrective action relative to the expected improvement, noting any additional analysis or action taken, and plan to achieve the CLOS target.
- d) The below Figure 3-2 illustrates the formatting for FRACAS Report Part 2A using the example of various corrective actions implemented from 2017 through 2020 to improve CLOS target of GO Train On Time Performance (OTP) Negative Performance Measure (NPM) and potential corrective actions which have been recommended for future implementation relative to the same CLOS target.

Figure 3-2 FRACAS Report PART 2A - CLOS performance monitoring and planning

CLOS Target: 0.9% OTP NPM				
Improvement Achieved from Historical Corrective Actions				
Year	Expected Improvement		Achieved Improvement	
2017	0.15%		0.13%	
2018	0.18%		0.21%	
2019	0.09%		0.09%	
<b>Total</b>	<b>0.42%</b>		<b>0.43%</b>	
Implemented Corrective Actions Being Monitored				
Implementation Date	Corrective Action ID	Corrective Action Description	Expected Improvement	Trend
Feb-19	ID-19-1	Asset Category D System D-1 redesign to eliminate failure mode X	0.19%	●
Jul-19	ID-19-2	Introduction of new maintenance task X	0.05%	●
Jan-20	ID-20-1	Install monitoring system for Asset Category A	0.08%	●
<b>Total Expected Improvement</b>			<b>0.32%</b>	
<b>Expected Gap to Target</b>			<b>0.85%</b>	
Recommended Future Corrective Actions				
Date Recommended	Source ID	Corrective Action Description	Potential Improvement	Stage
Mar-19	RCA XXXX	Asset Category B Refurbishment	0.30%	IP Approval
Jan-20	RCA YYYY	Maintenance Task X Tolerance Change	0.05%	Team Approval
Feb-20	RCA ZZZZ	New incoming quality check for component Y	0.10%	Team Approval
<b>Total Potential Improvement</b>			<b>0.45%</b>	
<b>Potential Gap to Target</b>			<b>0.40%</b>	

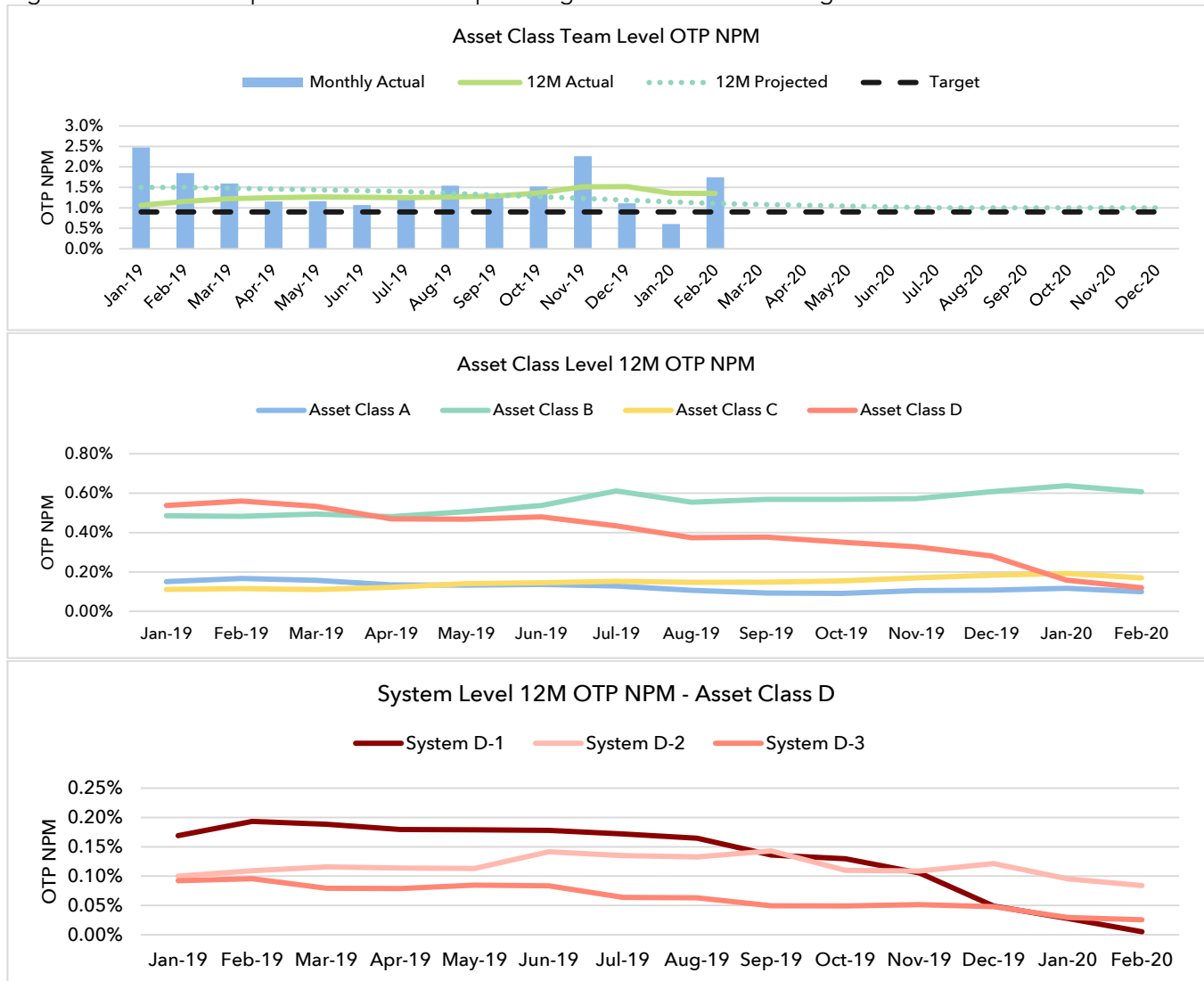


**Analyst Comments:**  
 OTP NPM continues to decrease in line with the expected improvement from implemented corrective actions year over year, however it remains significantly above the target of 0.9%. The corrective actions currently implemented for 2020 are all on track to achieve the expected improvement, however this will still leave a 0.85% gap to the target value. Three additional corrective actions have been recommended for implementation, however if these were implemented and fully realized, this would still leave a 0.40% gap to the target value. The team is working to identify additional opportunities to develop a plan to achieve the OTP NPM target (ECD June 2020).

- 3.2.5 The FRACAS Report Part 2B shall include the following information for each CLOS target applicable to the asset class team:
- a) The first chart shall provide a breakdown to the asset class team level actual and projected performance against the target, where projected performance takes into account the expected cumulative effects of all corrective actions implemented as detailed in the FRACAS Report Part 1 for the individual asset class team [detailed in Section 3.1]
  - b) The second chart provides a further breakdown to individually show the contribution of each Asset Class's performance on CLOS target.
  - c) The third chart provides a further breakdown for one of those Asset Classes to its System Level contribution.
  - d) This breakdown should continue to be expanded on within Part 2B of the FRACAS Report to the extent that the major asset classes and systems with highest influence to CLOS target is clearly understood.
- 3.2.6 The below Figure 3-3 illustrates the formatting for FRACAS Report Part 2B using the example of GO Train On Time Performance (OTP) Negative Performance Measure (NPM) as the CLOS target. This example uses both monthly and twelve month rolling (12M) actual performance figures for over twelve months total, however, the appropriate measures and timeframe may vary for different CLOS targets. Regardless of CLOS target, the overall formatting shall be consistent as shown with breakdowns through the appropriate functional asset hierarchies.
- 3.2.7 Additionally, the example shown in Figure 3-3 only provides analyst comments at the lowest functional asset hierarchy level analyzed, however, comments may be included elsewhere as appropriate to provide context to understand the charts and summarize analysis performed and actions in work, as warranted.



Figure 3-3 FRACAS Report PART 2B - example using OTP NPM as CLOS target



**Analyst Comments:**

Overall asset class team Level OTP NPM remains above target though continues to trend downwards as per the 12 M projection and is on track to reach the target in Q1 2021. However, OTP NPM is not decreasing as projected, and actually showed an increase in the impact from 2019 to 2020 thus far. Asset Class D System D-3 OTP NPM continues to improve on-target [\*insert reference to appropriate corrective action in report Part 1 for details\*], however Asset Class B now continues to be the highest contributor to OTP NPM, with Root Cause Analysis in progress ECD April 2020 [\*insert RCA number for reference\*].

### 3.3 PART 3: Asset RAM Performance

3.3.1 The purpose of Part 3 of the FRACAS Report is to identify opportunities for asset reliability, maintainability, and availability optimization, while ensuring safety levels are not negatively impacted.

3.3.2 The input data required for Part 3 is as follows:

- a) Failure Data [detailed in Section 2.1] is required to understand the quantity of failures.
- b) Utilization Data [detailed in Section 2.2] is required to understand the failure rates relative to the appropriate measure of utilization for asset reliability, maintainability, and availability calculations.
- c) Maintenance Data [detailed in Section 2.3] is required to understand the frequency of maintenance activities and downtime associated for asset maintainability calculations.
- d) RAM Target data & Industry Benchmarking data [detailed in Section 2.5] is required to set appropriate targets to understand how the actual reliability, maintainability, and/or availability compare to the target and/or industry benchmarking values.

3.3.3 The output measures of RAM performance shall include, but are not limited to:

- a) Maintainability Measures:
  - 1) Mean Time Between Maintenance (MTBM), which is a measure of how often maintenance is performed relative to the time the item is in use (or other utilization dimension as appropriate).
  - 2) Mean Down Time, which is a measure of the amount of time between the discovery of a failure and the restoration to the regular operational state.
- b) Reliability Measures:
  - 1) For repairable items: Mean Time Between Failures (MTBF), which is a measure of how often a failure occurs relative to the time the item is in use (or other utilization dimension as appropriate).
  - 2) For non-repairable items: Mean Time To Failure (MTTF), which is a measure of how long (time or other utilization dimension as appropriate) the item may continue to operate before a failure is expected to occur.
- c) Asset Availability, which is a measure of the percentage of time that an asset is in operation, relative to time in a failed state and in maintenance.

**Note:** MTBM may be split between Preventive Maintenance as MTBM(p) and Corrective Maintenance as MTBM(c) as warranted.

**Note:** for additional details on RAM calculations and formulas, refer to section 5.

3.3.4 Part 3 of the FRACAS Report shall be formatted as data tables, with information shown through the functional asset hierarchies as available. Figure 3-4 shows a template with the minimum data requirements to be included in the FRACAS Report Part 3. Additional data may be included as available and appropriate to support regular FRACAS review and analysis.

3.3.5 The below Figure 3-4 shows an empty table to illustrate the formatting for FRACAS Report Part 3 for a simple functional asset hierarchy composed of one Asset Class "X" composed of at least one Asset Category "X-1", which is in turn made up of multiple Systems. System "A"



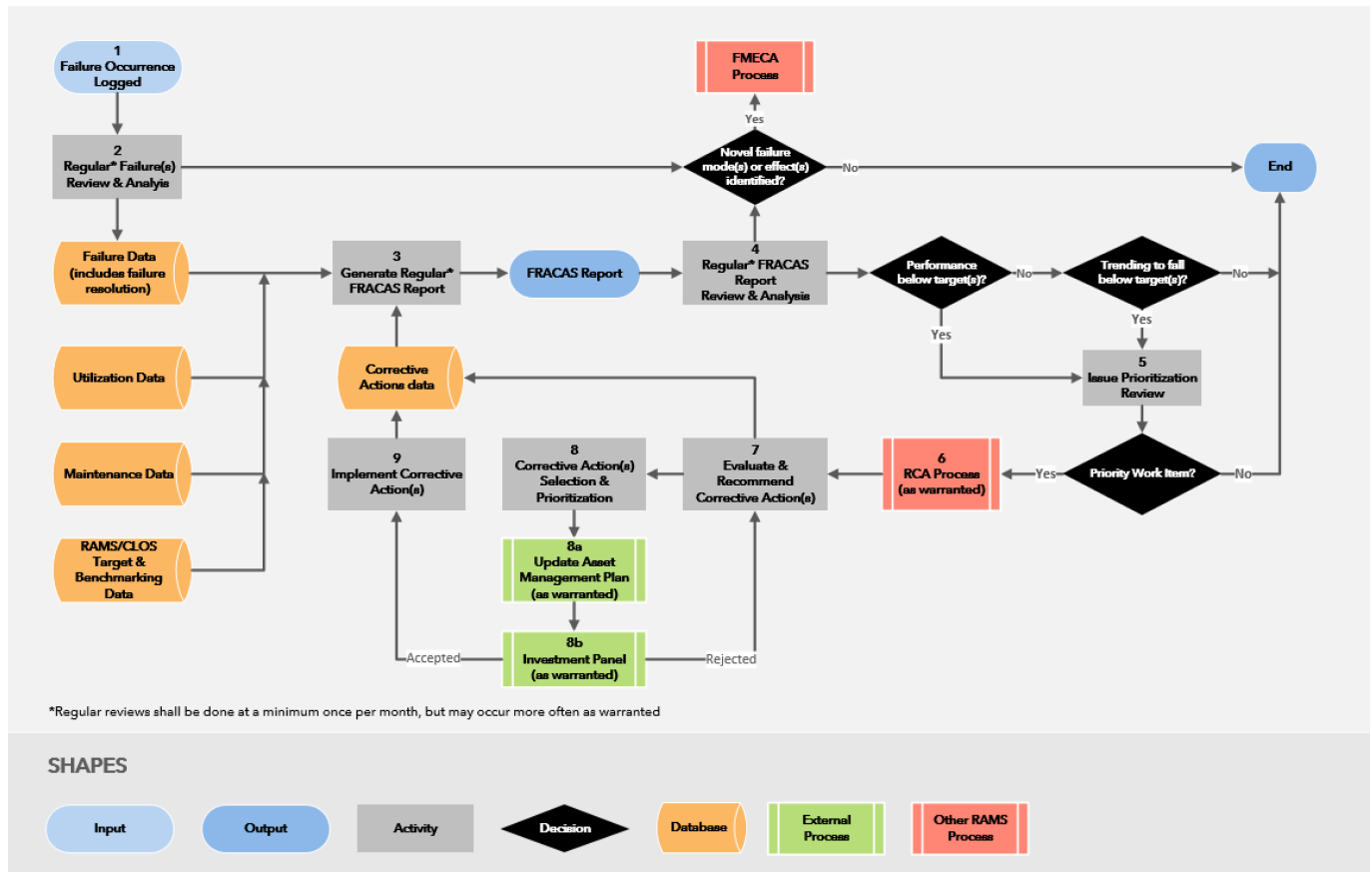


# 4. The FRACAS Process

## 4.1 The FRACAS Process Flow Chart

4.1.1 Figure 4-1 illustrates the FRACAS Process<sup>1</sup>.

Figure 4-1 The FRACAS process - detailed process



<sup>1</sup>For additional details on process activities, please refer to the process narrative on subsequent page(s).

## 4.2 The FRACAS Process Narrative

4.2.1 The following steps describe the Failure Reporting and Corrective Action System (FRACAS) Process:

- 1) Failure occurs on an asset in operation and maintenance life cycle phase and that failure is logged and reported to the asset class team.
- 2) The asset class team shall perform a regular review and assessment of the failure data (at least once per month) and the failure data shall be stored and updated as required in accordance with the FRACAS standard data requirements [detailed in Section 2.1]. Additionally, any novel failure modes or failure effects observed during operation and maintenance shall initiate an update to the appropriate FMECA documentation [RAMS-2].

- 3) Failure data shall be reported along with asset utilization data [detailed in Section 2.2], maintenance data [detailed in Section 2.3], corrective action data [detailed in Section 2.4], and RAMS & CLOS target & benchmarking data [detailed in Section 2.5] in the FRACAS Report [detailed in Section 3], which shall be generated regularly (at least once per month).
- 4) Asset class teams shall perform a regular review and analysis (at least once per month) of the FRACAS Report for any negative trends in the actual reliability and/or performance relative to the target and/or expected values. Additionally, any novel failure modes or failure effects observed during operation and maintenance shall initiate an update to the appropriate FMECA documentation [RAMS-2].
  - a) In the case where actual reliability or performance is above target and trending to remain above target, no action further action is required.
  - b) In the case where actual reliability or performance is consistently below target, this should be considered a top issue and action should be taken per step 4).
  - c) In the case where actual reliability or performance is above target, but is trending towards not meeting the target, this should be considered an issue and action should be taken per step 4).
- 5) Asset class teams shall prioritize the identified issues for further analysis and corrective action.
- 6) Asset class teams shall determine if the root cause is fully understood and documented. If the root cause is not fully understood, initiate a Root Cause Analysis [RAMS-4].

**Note:** refer to RCA process [RAMS-4] for details on determining whether an RCA is appropriate and required.

- 7) Asset class teams shall identify the corrective action(s) required to resolve the reliability and/or performance issue and evaluate the potential effect(s) of implementing the corrective action(s) on the reliability/performance. The corrective action(s) as well as their expected effect(s) on reliability/performance and any assumptions made shall be documented [detailed in Section 2.4].
- 8) Asset class teams shall select and prioritize the corrective action(s) that will be implemented and implement them, with approval from the Investment Panel (IP) as required through use of the Asset Management Plan to justify investment.
- 9) Each corrective action implemented shall be monitored through the regular FRACAS Report review and analysis to ensure that the intended effect(s) of the corrective actions implemented are reflected in operation (trend monitoring). This monitoring shall only end after the full effect of the corrective action has been realized in operation. If the corrective action(s) implemented did not resolve the reliability/performance issue to achieve or exceed the targeted effect, return to step 4).
- 10) The FRACAS process shall be maintained by all asset class teams for the duration that their assets are in operation.

**END: The process ends here**

## 5. Definition of FRACAS Equations

### 5.1 Reliability Calculations

5.1.1 The reliability parameters that shall be used in FRACAS are as follows:

- a) MTBF (Mean Time Between Failures), which is used for repairable assets

$$MTBF = \frac{\text{Total Utilization (within defined time period)}}{\text{Total Number of Failures (within the same defined time period)}}$$

- b) MTTF (Mean Time To Failures), which is used for non-repairable assets

$$MTTF = \frac{\sum_{i=0}^n \text{asset lifetime utilization}}{n}, \text{ where } n = \text{the number of assets}$$

$$\cong \frac{\text{Total Utilization (within defined time period)}}{\text{Total Number of Failures (within the same defined time period)}}$$

5.1.2 The following are other examples of reliability parameters which may be used in FRACAS as warranted:

- a)  $\lambda(t)$  (Failure Rate), where (t) is the applicable measure of asset utilization

$$\lambda(t) = \frac{1}{\text{MTBF (or MTTF for non repairable assets)}}$$

$$= \frac{\text{Total Number of Failures (within a defined time period)}}{\text{Total Utilization (within the same defined time period)}}$$

### 5.2 Maintainability Calculations

5.2.1 The maintainability parameters that shall be used in FRACAS are as follows:

**Note:** maintainability parameters may be split between Preventive Maintenance (i.e. MTBM(p)) and Corrective Maintenance (i.e. MTBM(c)) as warranted.

- a) MTBM (Mean Time Between Maintenance)

$$MTBM = \frac{\text{Total Utilization (within defined time period)}}{\text{Total Number of Maintenance Events (within the same defined time period)}}$$

- b) MDT (Mean Downtime)

$$MDT = \frac{\text{Total downtime (within defined time period)}}{\text{Total Number of Maintenance Events (within the same defined time period)}}$$

5.2.2 The following are other examples of maintainability parameters which may be used in FRACAS as warranted:

- a) MTTM (Mean Time To Maintain)

$$MTTM = \frac{\text{Total CM \& PM Labour Hours (within defined time period)}}{\text{Total Number of Maintenance Events (within the same defined time period)}}$$

- b) MRT (Mean Repair Time)

$$MRT = \frac{\text{Total CM Labour Hours (within defined time period)}}{\text{Total Number of Maintenance Events (within the same defined time period)}}$$

c) MTTR (Mean Time to Restore)

$$MTTR = \frac{\text{Total downtime due to Corrective Maintenance (within defined time period)}}{\text{Total Number of Corrective Maintenance Events (within the same defined time period)}}$$

d) MUT (Mean Up Time)

$$MUT = MTBF \text{ (or } MTTF \text{ for non repairable assets)} - MDT$$

## 5.3 Availability Calculations

5.3.1 The availability parameters that shall be used in FRACAS are as follows:

a) A (Availability)

$$A = \frac{MUT}{MUT + MDT}$$