Metrolinx
RAMS Process Standard

MX-SEA-STD-100

Revision 00
Date: April 2023

RAMS Process Standard

MX-SEA-STD-100

Publication Date: April 2023

COPYRIGHT © 2023

Metrolinx,

an Agency of the Government of Ontario

The contents of this publication may be used solely as required for services performed on behalf of Metrolinx or for and during preparing a response to a Metrolinx procurement request. Otherwise, this publication or any part thereof shall not be reproduced, re-distributed, stored in an electronic database or transmitted in any form by any means, electronic, photocopying or otherwise, without written permission of the copyright holder. In no event shall this publication or any part thereof be sold or used for commercial purposes.

The information contained herein or otherwise provided or made available ancillary hereto is provided "as is" without warranty or guarantee of any kind as to accuracy, completeness, fitness for use, purpose, non-infringement of third party rights or any other warranty, express or implied. Metrolinx is not responsible and has no liability for any damages, losses, expenses or claims arising or purporting to arise from use of or reliance on the information contained herein.

Amendment Record

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

Preface

This is the first edition of the RAMS Process Standard published as part of Metrolinx RAMS (Reliability, Availability, Maintainability and Safety) Standards. It describes an overview of the Systems Engineering Assurance process including an overview of the deliverables, reviews and available resources including applicable standards.

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, review 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; CMREA, and ISO 15288, 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 Systems Engineering Assurance Office, Engineering and Asset Management Division, Metrolinx.

Suggestions for revision or improvements can be sent to the Metrolinx Systems Engineering Assurance office at Engineering.Assurance@metrolinx.com. The Director of the Systems Engineering Assurance office authorizes the changes. 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.

April 2023

Contents

Figures

Tables

Documents

TABLE 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) (Part 1: Generic RAMS Process)	Parent Standard
BS EN 50126-2:2017	Railway Applications – The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS) (Part 2: Systems Approach to Safety)	Parent Standard
ISO/IEC/IEEE 15288:2015 -	System Life Cycle Processes	Parent Standard
MX-ALM-STD-001	Asset Data and Information Standards	Reference
MX-SEA-STD-007	Requirements Management	Reference
FevCKH-ENG-FRM-008	Standards Deviation Request Form	Reference
CKH-ENG-PRC-001	Procedure for Requesting Deviations to Metrolinx Standard Technical Requirements	Reference
CPG-QAT-FRM-106	CPG Terms Glossary	Reference
CSA R114-22	Canadian Method for Risk Evaluation and Assessment for Railway Systems (CMREA)	Parent Standard
MX-SEA-TOR-001	Metrolinx System Review Panel (SRP) Terms of Reference (ToR)	Review Panel ToR
April 5, 2023	Metrolinx Safety Certification Committee (SSC) Terms of Reference (ToR)	Certification Committee ToR

Acronyms and Abbreviations

TABLE 2 ACRONYMS AND ABBREVIATIONS

Acronym	Full Name
AFP	Alternative Financing and Procurement
AIP	Approval In Principle
CMREA	Canadian Method for Risk Evaluation and Assessment for Railway Systems CSA R114-22
CPG	Capital Projects Group
CTC	Consent To Construct
CTO	Consent To Operate
CTT	Consent To Test
ESAC	Engineering Safety and Assurance Case
FMECA	Failure Modes Effects & Criticality Analysis
FRACAS	Failure Reporting, Analysis and Corrective Action System
ID	Identification
IP	Investment Panel
ISA	Accredited Independent Safety Assessor against CMREA, EN 50126/8/9
PDD	Process Description Document
PFD	Process Flow Diagram
RACI	Responsible Accountable Consulted Informed
RAM	Reliability, Availability and Maintainability
RAMS	Reliability, Availability, Maintainability and Safety
RCD	Reference Concept Design
SCC	Safety Certification Committee
SDS	System Design Safety (Also referred to as System Design Safety)
SEA	Systems Engineering Assurance
SRP	System Review Panel
ToR	Terms of Reference
V&V	Verification & Validation

Definitions

Table 3 Definitions

Term	Definition	Source
acceptance	Status achieved by a product, system or process once it has been agreed that it is suitable for its intended purpose	EN 50126-1:2017
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 provided	EN 50126-1:2017
Asset owner	Groups and individuals that are responsible for asset ownership, asset maintenance, inventory management, document control, asset handover and reliability engineering	MX-ALM-STD-001
compliance	State where a characteristic or property of a product, system or process satisfies the specified requirements	EN 50126-1:2017
configuration management	Process of identifying and documenting the characteristics of a facility's structures, systems and components (including computer systems and software), and of ensuring that changes to these characteristics are properly developed, assessed, approved, issued, implemented, verified, recorded and incorporated into the facility documentation	EN 50126-1:2017
design	Activity applied in order to analyze and transform specified requirements into acceptable solutions	EN 50126-1:2017
failure	Loss of ability to perform as required	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	EN 50126-1:2017
hazard	Condition that could lead to an accident	EN 50126-1:2017
hazard analysis	Process of identifying hazards and analyzing their causes, and the derivation of requirements to limit the likelihood and consequences of hazards to a tolerable level	EN 50126-1:2017
Hazard Record	Document in which hazards identified, decisions made, solutions adopted, and	EN 50126-1:2017

	their implementation status are recorded or referenced. This term is equivalent to "Hazard Log" as used in EN 50126-1:2017.	
implementation	Activity applied in order to transform the specified designs into their realization	EN 50126-1:2017
independent safety assessment	Process to determine whether the system/product meets the specified safety requirements and to form a judgement as to whether the system/product is fit for its intended purpose in relation to safety	EN 50126-1:2017
integration	Process of assembling the elements of a system according to the architectural and design specification, and the testing of the integrated unit	EN 50126-1:2017
Investment Panel	Stakeholder group within Metrolinx whose responsibilities include approving capital project stage gate progression, including initiating capital programs and projects, approving capital project changes, and monitoring the status of projects/programs.	Metrolinx Capital Project Approvals Policy
IP Stage	The Metrolinx Capital Project Approvals Policy defines seven project stages to facilitate Investment Panel oversight: Stage 0: Define Stage 1: Assess Stage 2: Develop Stage 3: Design Stage 4: Build Stage 5: Operate Stage 6: Closeout	Metrolinx Capital Project Approvals Policy
IP Stage Gate	A project review by the Investment Panel where approval is required for the project to proceed the next stage. IP stages 1-5 have IP Stage Gates.	Metrolinx Capital Project Approvals Policy
life cycle	Series of identifiable stages through which an item goes, from its conception to disposal	EN 50126-1:2017
maintainability	Ability to be retained in, or restored to, a state to perform as required, under given conditions of use and maintenance	EN 50126-1:2017
maintenance	Combination of all technical and management actions intended to retain an	BS EN 50126-1:2017

	item in, or restore it to, a state in which it can perform as required	
mission	Objective description of the fundamental task performed by a system	BS EN 50126-1:2017
mission profile	Outline of the expected range and variation in the mission with respect to parameters such as time, loading, speed, distance, stops, tunnels, etc., in the operational phases of the life cycle	BS EN 50126-1:2017
Non-Significant Change	A modification to the railway that is **not** considered "Significant" as per CMREA	CSA R114-22
Planning/ Sponsors Office	The Planning and Sponsorship Office is responsible for defining the project and ensuring the benefits are realized. They establish the project, secure funding and provide strategic oversight.	Planning, Design, and Sponsorship Office homepage, CKH-QMA-FRM-003
Project Company	The private sector entity which enters into the Project Agreement with Infrastructure Ontario and Lands Corporation and Metrolinx to design, build and where applicable, finance, operate or maintain a Project. The special-purpose entity which has entered into a Project Agreement with the Contracting Authority.	CKH-QMA-FRM-003
Project Manager	Appointed by Metrolinx as its representative and is responsible for the delivery of the Project within the prescribed Schedule and budget. Metrolinx employees fulfilling the role of the Project Manager may also be considered the Cost Centre Manager, if this person is also delegated signing authority in accordance with the Metrolinx Corporate Administrative Manual, Administrative Management, Approval Authorization Controls and Designations. It is noted that non-Metrolinx employees fulfilling the role of the Project Manager are not considered Cost Centre Managers. In such cases refer to approved Project Chart of Accounts for the Program for the designated Cost Centre Manager.	CKH-QMA-FRM-003

railway duty holder	Body with the overall accountability for operating a railway system within the legal framework	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
risk	Combination of expected frequency of loss and the expected degree of severity of that loss	BS EN 50126-1:2017
risk analysis	Systematic use of available information to identify hazards and to estimate the risk	BS EN 50126-1:2017
risk assessment	Overall process comprising a risk analysis and a risk evaluation	BS EN 50126-1:2017
risk evaluation	Procedure based on the risk analysis to determine whether the tolerable risk has been achieved	BS EN 50126-1:2017
risk management	Systematic application of management policies, procedures and practices to the tasks of analyzing, evaluating and controlling risk	BS EN 50126-1:2017
safety	Freedom from unacceptable risk	BS EN 50126-1:2017
safety case	Safety case documented demonstration that the product (e.g. a system, subsystem or equipment) complies with the specified safety requirements	BS EN 50126-1:2017
Safety Certification Committee	The Safety Certification Committee, under the authority of the Metrolinx Chief Safety Officer, promotes the safety, efficiency and protection of transportation corridors by ensuring appropriate structures, practices and policies are in place for any changes to the rail transportation network. The purpose of the Metrolinx Safety Certification Board is to: (a) ensure that any proposed Significant Change to transportation infrastructure or operations that may affect the safety of the public or personnel or the protection of property or the environment is design, constructed, commissioned and operated safely; (b) provide safety approvals at various stages of a project for the project proponent to be able to proceed to the next stage after having provided appropriate evidence of the management of safety risks; and	Metrolinx Safety Certification Board Terms of Reference

	(c) be accountable to the Audit, Finance, and Risk Management Committee of the Metrolinx Board of Directors that the mandate of the Metrolinx Safety Certification Board is being fulfilled. that the two components of promoting the safety, efficiency and protection of the transportation corridors are addressed. The SCC has the specific mandate related to the duties of the corporation and the regulatory accountability of the Chief Safety Officer. The membership of the committee is comprised of senior executives within the organization.	
Significant Change	A Significant Change (refer to definition of "Significant Change" in section 5 of CMREA) means a change that could has a potential impact on the safety of the railway system.	CSA R114-22
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
System Review Panel	A group include Engineering Directors or delegates, representing each discipline in Engineering & Asset Management, Systems Engineering Assurance, Systems Safety Assurance, and Operations.	N/A
testing	Determination of one or more characteristics of an object of conformity assessment, according to a procedure	BS EN 50126-1:2017
validation	1. Confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled *Note 1 to entry: The term "validated" is used to designate the corresponding status.* *Note 2 to entry: The use conditions for validation can be real or simulated.* *Note 3 to entry: In design and development, validation concerns the process of examining an item to determine conformity with user needs.* *Note 4 to entry: Validation is normally performed during the final stage of development, under defined operating conditions, although it can also be performed in earlier stages.*	1. BS EN 50126-1:2017 Section 3 2. BS EN 50126-1:2017 Section 6.7.3

	Note 5 to entry: Multiple validations can be carried out if there are different intended uses. 2. (In life cycle phase 4) "Specification of System Requirements", validation has the aim to assure that system requirements (including RAMS requirements) have been properly specified applying the requirements defined in this standard and any additional specific requirements defined by applicable legal framework.	
verification	1. Confirmation, through the provision of objective evidence, that specified requirements have been fulfilled *Note 1 to entry: The term "verified" is used to designate the corresponding status.* *Note 2 to entry: Design verification is the application of tests and appraisals to assess conformity of a design to the specified requirement.* *Note 3 to entry: Verification is conducted at various life cycle phases of development, examining the system and its constituents to determine conformity to the requirements specified at the beginning of that life cycle phase.* 2. The objective of verification is to demonstrate that the requirements of each life cycle phase have been fulfilled.	1. BS EN 50126-1:2017 Section 3 2. BS EN 50126-1:2017 Section 6.7.2

1. Overview

1.1 Purpose

1.1.1 The goal of the RAMS process is to ensure that considerations for reliability, availability, maintainability and safety are embedded in the development and delivery of transit projects.

1.1.2 This document provides an overview of the RAMS (Reliability, Availability, Maintainability, Safety) deliverables in the project system life cycle which applies to Systems Engineering Assurance. It describes the overall goals of the process, the RAMS specific reviews and deliverables as well as how the process aligns with Metrolinx project stages. The intent of this document is to describe a process that is compliant with EN 50126-1:2017 and how it aligns with organizational context of Metrolinx.

1.1.3 This standard establishes consistent expectations for the content, quality and timing of system assurance deliverables and reviews.

1.1.4 Application of this standard does not absolve the Project Company of the responsibility to exercise good engineering judgement, including the application of other standards that are legally or contractually required or generally expected within industry for a given application.

1.2 Applicability

1.2.1 This process is mandatory for any project that undertakes a technical change to the railway system (i.e. introduction of a new subsystem, renewal of an existing subsystem, a modification to an existing subsystem, or introduction of a new or modified maintenance regime) or undertakes an operational change to the railway system.

1.2.2 This process is not applicable for established routine maintenance activities including like-for-like replacement of components.

1.2.3 It is recognized that Metrolinx and its suppliers undertake a wide variety of activities, it is expected that the documentation produced be appropriate for the level of complexity and risks included in the project scope.

1.2.4 This standard is applicable for all asset classes. This product is considered good practice when developing or modifying any complex system.

1.2.5 If any of the deliverables are not applicable based on the project scope, the SRP Secretary may be contacted to have an exemption approved. Exemptions should be documented in the ESAC submissions.

1.3 Scope

1.3.1 This document provides an overview of the RAMS process, its deliverables, their interdependencies and the required reviews.

1.3.2 Product Descriptions specify the requirements for each deliverable. In instances where this document conflicts with a Product Description, the Product Description is accepted as being the defining document. Any inconsistencies should be reported to the Systems

Engineering Assurance group for resolution. A list of RAMS documents including Standard, Product Descriptions, Guidance and Templates are included in Appendix AA.3.

1.3.3 Section 3 provides an overview of the whole lifecycle of a project, from concept to decommissioning. It describes the goals and deliverables of each project phase. Though Capital Projects typically are completed once the system has been accepted by the operating organization, discussion of system operation and decommissioning are included, to show how capital project work impacts the operation and decommissioning of the system. Figure 1 shows an overview of the different phases.

1.3.4 Section 4 provides an overview of the RAMS design reviews that occur throughout the system lifecycle, the focus of each review and how the reviews will typically align with the Metrolinx IP Stage Gates.

1.3.5 Deviations from this standard are managed as per CKH-ENG-PRC-001 and CKH-ENG-FRM-008. Deviations may be necessary for contracts established before implementation of this standard.

1.3.6 This document includes a description of the process for projects that include Significant Changes and non-Significant Changes under CMREA.

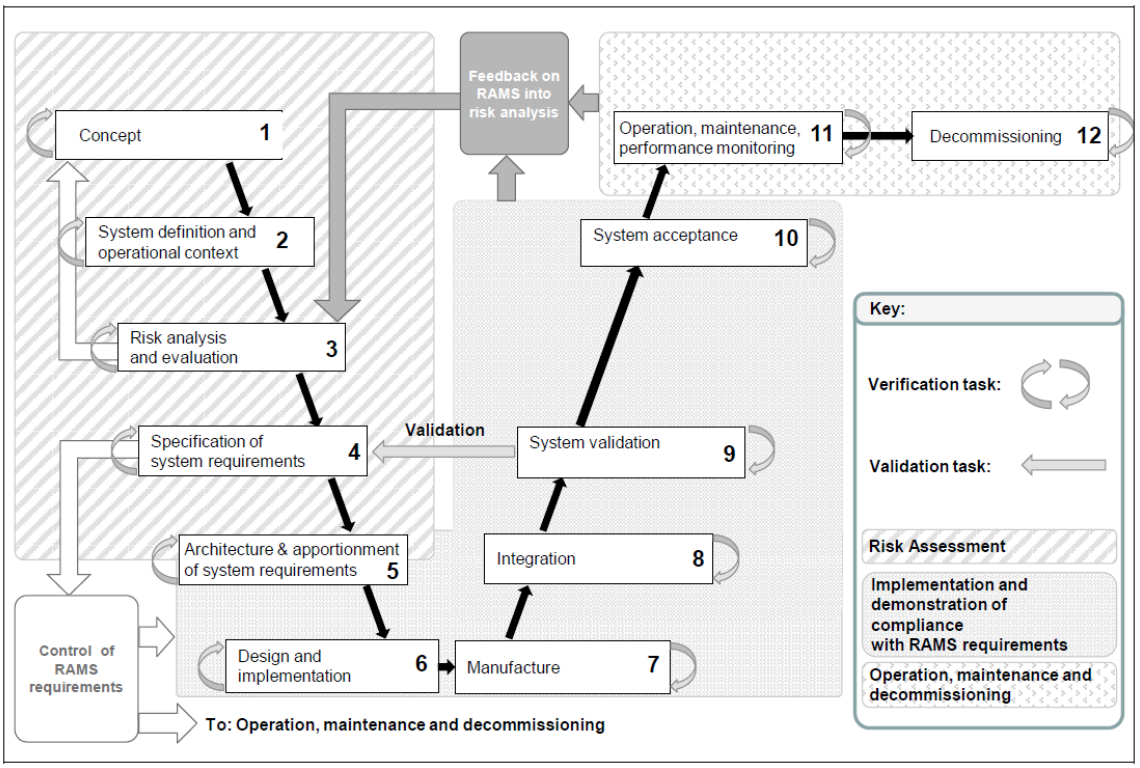


Figure 1 The interrelation of RAMS management process and system life cycle - the V-Cycle representation [Source: BS EN 50126-1:2017][1]

[1] Risk analysis is an ongoing and iterative step and can continue in parallel with subsequent phases.

1.4 Roles & Responsibilities

1.4.1 The Responsible, Accountable, Consulted and Informed (RACI) information in Table 4 sets out the interaction between the stakeholders involved in the production and endorsement of the product.

1.4.2 The RACI does not specify that the stakeholders mentioned below need to hold any specific competences outside their job role.

1.4.3 Where stakeholders detailed in the RACI are the author or the reviewer of a product, they shall hold the competencies detailed in the competence section of the product description standard for that product.

1.4.4 The roles are defined as per Table 3 Definitions.

1.4.5 If a role is preceded by "Metrolinx" it refers to a person or group within Metrolinx or a delegate representing the interests of Metrolinx.

1.4.6 If a role is preceded by "Project" it refers to a person or group within the Project Company.

1.4.7 Some of the Asset Owner obligations and responsibilities may be transferred through contracting, whereby the contract contains Reliability, Availability, Maintainability and Safety (RAMS) and operating requirements. The Metrolinx Asset Owner would participate in endorsing the relevant assurance products whereas a contracted party responsible for RAMS would develop the relevant assurance products, as directed by the Project Management.

1.4.8 Roles within the Project Company must comply with independence requirements for design, verification, validation and ISA activities as described in EN 50126-2:2017, section 7.

1.4.9 The responsibilities are summarized below in Table 4 using the following terms:

a) **R-Responsible** for the content and quality of the product when either producing or endorsing.

b) **A-Accountable** for ensuring that the product is completed and endorsed by the responsible stakeholders.

c) **C-Consulted** parties are expected to be affected by the content of the product. They are to be consulted during the production and review of the product whenever possible.

d) **I-Informed** parties are only expected to be rarely affected directly by the content of the product and are provided the information so they may determine the appropriate level of involvement.

TABLE 4 RAMS RACI

				Metrolinx						Project	
Product(s)	EN 50126 Life Cycle Phase	Metrolinx IP Stage	Action	Planning/ Sponsors Office	Project Management	Asset Owner*	Metrolinx ISA	System Review Panel (SRP)*	Safety Certification Committee (SCC)	Project Company	Project ISA
Railway Level Safety Plan, Preliminary Railway Level System Definition	Phase 1	Stage 1 (only required for major programs)	**Produce**	A	I	C	I	I	I	R	I
			Endorse	A	I	C	C	R	R	I	I
Preliminary System Definition	Phase 1	Stage 1	**Produce**	A	I	C	I	I	I	R	I
			Endorse	A	I	C	C	R	R	I	I
System definition, System Safety Plan, RAM Plan, RAM Analysis Process	Phase 2	Stage 2 (AIP gate submission)	**Produce**	A	I	C	I	I	I	R	I
			Endorse	A	I	C	C	R	R	I	I
	Phases 3 - 10	Stages 3 & 4 (Update for SDS through CTO gates)	**Update**	I	A	C	I	I	I	R	I
			Endorse revisions	I	A	C	C	R	R	I	I
Preliminary System Safety Case, System Safety Case	Phases 3 - 10	Stages 2 - 4 (ALL gates submission)	**Produce & Update**	-	A	C	I	C	C	R	I
			Endorse (including revisions)	-	A	C	C	R	R	I	I
ISA Plan, ISA Report	Phases 1 - 10	Stages 1 - 4 (ALL gates submission)	**Produce & Update**	-	A	I	I	I	I	I	R
ESACs	RAMS Gates*	Stages 1 - 4 (ALL gates submission)	**Produce**	-	A	C	I	I	I	R	I
			Endorse	I	A	C	C	R	R	I	I
All other assurance products (see Appendix A)	Phases 2 - 10	Stages 1 - 4 (ALL gates submission)	**Produce & Update**	-	A	C	I	I	I	R	I
			Endorse (including revisions)	-	A	C	C	R	R	I	I

***Table 4 Notes:**

RAMS Gates include AIP, SDS, CTC, CTT, CTO Gates as per section 4

2. The RAMS Process

2.1 The RAMS Process Narrative

2.1.1 The following steps describe the RAMS Process as shown in Figure 1, Figure 2 and Figure 3:

1) A concept is identified and a Preliminary System Definition is developed. It is determined if the concept would constitute a Significant Change to the railway. An ISA plan is prepared if the change is Significant.

2) System Definition work is performed to fully understand the boundaries, interfaces and complexity of the scope and develop plans to address the RAMS project content.

3) The hazards associated with the system are identified and the Risk Analysis is started. The hazards and risks will need to be updated continuously throughout the project as new information becomes available. High-level RAMS targets are set, and the preliminary Safety Case and ISA Report (also referred to as the ISA ESAC Report) are prepared for submission. All deliverables are reviewed and approved before the Approval in Principle gate can be completed.

4) System requirements are developed based on inputs that include customer requirements, stakeholder input, standards, the results of the RAMS risk analysis and the Safety Related Application Conditions, which are also developed during this phase. The requirements are reviewed for completeness and quality, documented in the RAM & Safety Requirements Validation reports, then updated. While the requirements are being developed the Integration and Validation Plans are prepared. Previously submitted system documentation is updated as needed.

5) The System Architecture is developed, and the subsystem requirements are specified. All deliverables, including the ISA Report, are reviewed and approved before the System Design Safety Review gate can be completed. The SDS Review focuses on determining if the proposed system can satisfy needs of Metrolinx. The system design is assessed for compliance with the design requirements. System and subsystem requirements must be version controlled leading into the review.

6) Detailed design occurs. While the system is being designed more information becomes available. RAM Analysis is performed, and Operations, Maintenance, Training and Commissioning plans are prepared. Previously submitted system documentation is updated as needed, however any changes to design requirements must be approved by Metrolinx. All deliverables, including an updated ISA Report, are reviewed and approved before the Consent to Construct gate can be completed. The CTC gate focus is to determine if the designed system meets the established design requirements and project constraints (e.g. RAMS, budget, schedule).

7) The system is built and/or procured. The system may be inspected and/or tested as per the established Quality Management processes, or as specified in the Integration & Validation Plans. Previously submitted system documentation is updated as needed, however any changes to design requirements must be approved by Metrolinx. Test, Operations, Maintenance and Commissioning procedures are produced. All deliverables, including an updated ISA Report, are reviewed and approved before the Consent to Test review gate can be completed. The CTT gate focus is to ensure that testing can occur safely and that the tests will be performed in an organized manner.

The system design documentation and test procedures must be available, accurate and configuration controlled.

8) System Integration is performed. A FRACAS and configuration management process must be in place. The system is tested, and issues are resolved using the FRACAS and a configuration management process. The Integration Report is prepared to document these activities and any open issues. The system must be in a functional, known, documented and controlled configuration before Validation activities can begin. Previously submitted system documentation is updated as needed, however any changes to design requirements must be approved by Metrolinx.

9) Validation activities are performed. Including review of design, inspections, testing and analysis of the system in its current configuration. Issues that arise are resolved using the FRACAS and a configuration management process. Previously submitted system documentation is updated as needed, however any changes to design requirements must be approved by Metrolinx. The RAM and Safety Validation Reports are prepared.

10) The material documenting the integration and validation activities is summarized in the Acceptance Report, including any open issues. Open issues must be either resolved for accepted. Any system failures that occurred during testing, and corrective actions are summarized in the FRACAS Report. The system safety documentation, Operations, Maintenance, Training, and Commissioning Procedures are updated and finalized. All deliverables, including an updated ISA Report, are reviewed and approved before the Consent to Operate review gate can be completed. The CTO gate determines if the system can be put into operation. Once accepted, the assets and all documentation are transferred to operations.

11) The system is operated and maintained. Issues are tracked and managed through FRACAS. Changes to the system may require the safety documentation to be revisited. System documentation is updated as needed.

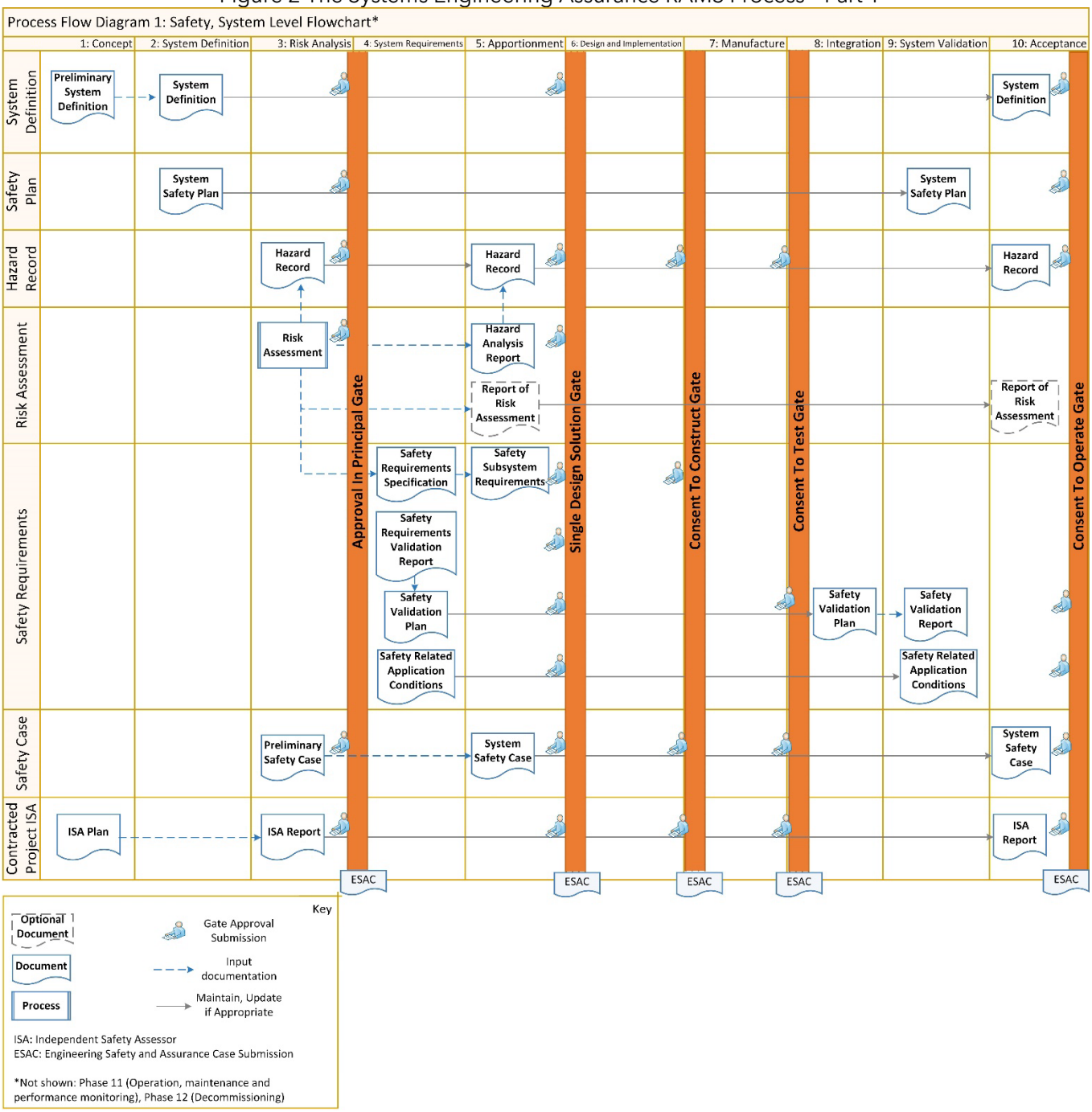
12) A decommissioning plan is prepared to ensure that the system can be safely decommissioned and disposed. The impact to external connected systems is assessed and managed before the system is decommissioned and disposed of as per the decommissioning plan.

END: The process ends here

2.2 The RAMS Process Flow Chart

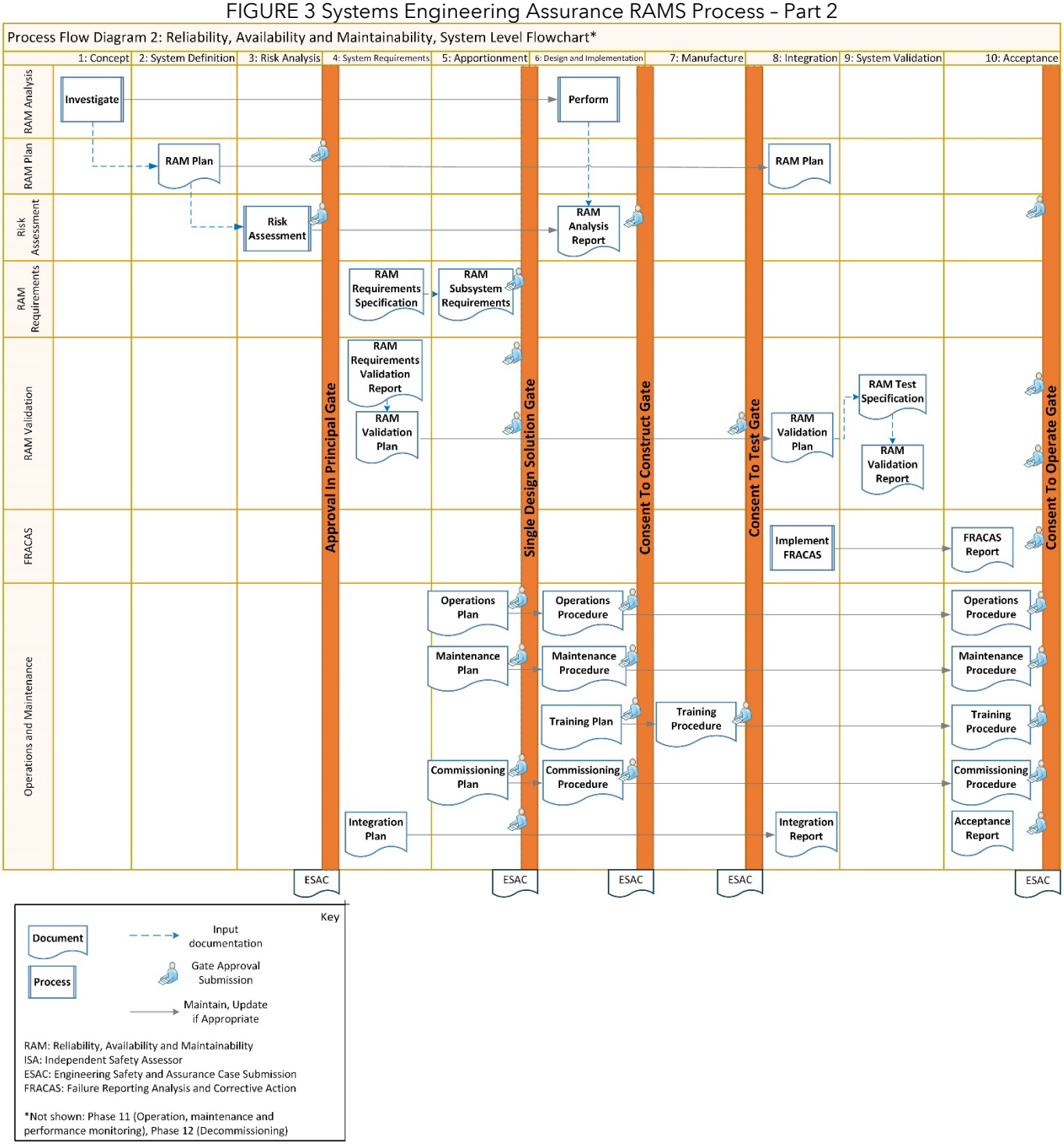
2.2.1 Figure 2 and Figure 3 illustrate the RAMS Process[2].

Figure 2 The Systems Engineering Assurance RAMS Process – Part 1



[2] For additional details on process activities, please refer to the process narrative

FIGURE 3 Systems Engineering Assurance RAMS Process – Part 2



3. RAMS Phases & Deliverables

3.1 Phase 1 - Concept

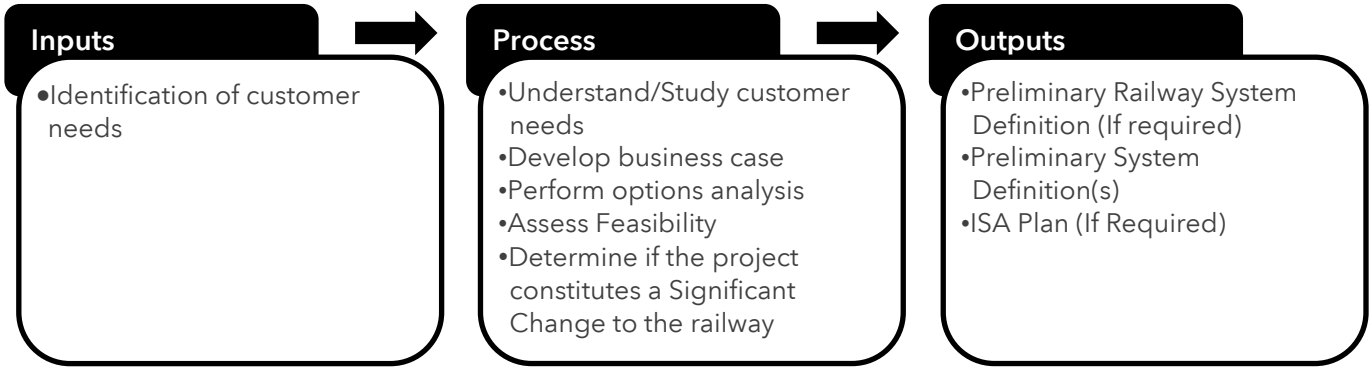
3.1.1 The concept phase is internal to Metrolinx. It includes all initial planning work which covers the initial business case and early options analysis, upon successful completion of this phase, the project is formally established. This phase aligns with Metrolinx IP Stages 0 & 1.

3.1.2 Following the request for a technical or operational change to the railway, a significance decision is made by following the CMREA; this determines whether an Independent Safety Assessor (ISA) is required. This is documented in the Preliminary System Definition.

3.1.3 If the change is Significant, an ISA will be appointed to the project who will prepare an ISA Plan detailing the safety assessment activities to be performed.

3.1.4 The role of the ISA is to determine whether the system/product meets the specified safety requirements and to determine if the system/product is safe to use

3.1.5 A single Preliminary System Definition document may be appropriate for a project, but for larger projects that represent a railway level change, a Preliminary Railway Level System Definition document is expected to coordinate the different scopes of work, each of which would also require their own Preliminary System Definition document.



3.2 Phase 2 - System Definition

3.2.1 The goal of the System Definition phase is to fully understand the scope of the project, in terms of its complexity and scale. The System Definition document (or documents) must be sufficiently detailed to support the development of system requirements, hazard analyses and RAM activities.

3.2.2 The System Definition document builds upon the Preliminary System Definition and the initial business case. Key information that must be included in the System Definition(s) include: a description of the system, its elements, the mission profile, system boundaries & interfaces, functions, operational requirements and constraints.

3.2.3 System Definition documents must be updated as the design matures to ensure alignment among project stakeholders.

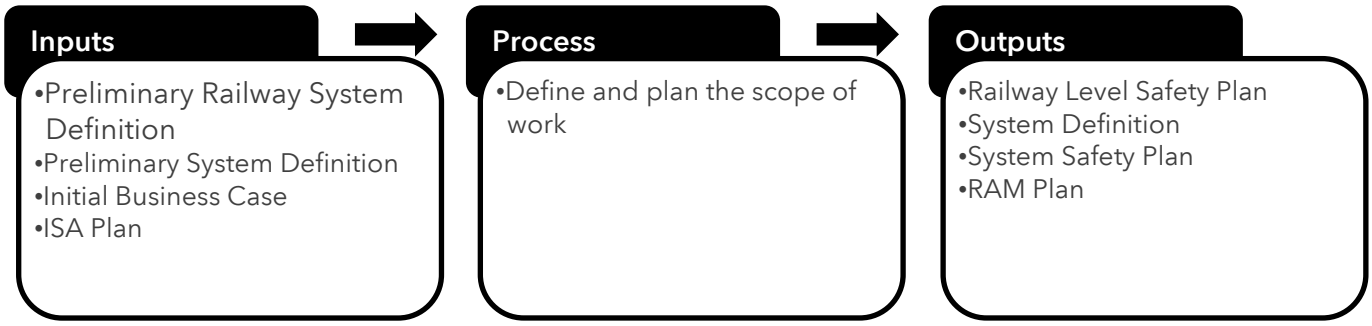
3.2.4 A RAM Plan is prepared based on the System Definition documents. The RAM Plan documents the RAM targets, RAM Policy, the scope of the RAM activities that will be completed during the project, the purpose of each activity, the methods & approach that will be used, and how the tasks will be sequenced & managed. The RAM Plan should provide enough detail to allow project leadership to determine the resources required to

complete the work, populate the tasks in the project schedule as well as provide project staff with guidance on their assigned tasks.

3.2.5 The RAM Plan is a considered a living document and shall be updated as information become available.

3.2.6 A System Safety Plan is prepared based on the System Definition documents and, if applicable, the ISA Plan. The System Safety Plan documents the Safety targets, the scope of the system safety activities that will be completed during the project, the purpose of each activity, the methods & approach that will be used, and how the tasks will be sequenced & managed. The System Safety Plan should provide enough detail to allow project leadership to determine the resources required to complete the work, populate the tasks in the project schedule as well as provide project staff with guidance on their assigned tasks.

3.2.7 A single System Safety Plan document may be appropriate for a simple project, but for larger projects that represent a railway level change, a Railway Level Safety Plan is expected to focus on railway level safety issues, manage interfaces and coordinate the different scopes of work, each of which also require their own System Safety Plan.



3.3 Phase 3 - Risk Analysis

3.3.1 The goal of the risk analysis phase is to identify hazards associated with the system throughout its lifecycle and to establish and document the framework that will be used by the project to manage safety and RAM risks.

3.3.2 The Hazard Record and risk assessment documentation need to be managed and updated continuously throughout the project and system lifecycle as the design matures.

3.3.3 The risk assessment relies on the System Definition document(s), to identify hazards and assess risks. It is expected that the existing documents will need to be updated as a result of the assessment.

3.3.4 As the risk assessment progresses, RAMS targets will be established for all functions based on their criticality. The risk assessment informs the development of the detailed RAMS system requirements in Phase 4.

3.3.5 Upon completion of this phase the first design review occurs to obtain approval in principle (AIP). The review process is described in Section 4.

3.3.6 The ESAC Submission is prepared to support the AIP review.

3.3.7 The Preliminary Safety Case is prepared based on the results of the risk assessment activities and Hazard Log.

3.3.8 The first ISA Report (also referred to as the ISA ESAC Report) submission is prepared independently for the AIP review, for projects that include a Significant Change.

*ISA Report is produced independently by the ISA for projects that include a Significant Change

3.4 Phase 4 - System Requirements

3.4.1 The goal of this phase is to establish an agreed upon set of detailed RAMS requirements for the system, including acceptance criteria and a verification and/or validation method for each requirement.

3.4.2 The Safety Related Application Conditions (SRAC) Report is prepared based on the risk analysis to support the development of requirements. The SRAC Report will need to be updated as the design matures.

3.4.3 The system design requirements are developed based on the System Definition, Initial Business Case, Risk Assessment, Hazard Record, System Safety Plan and RAM Plan that were completed previously.

3.4.4 The Safety Validation Plan, RAM Validation Plan and Integration Plan are prepared to identify resources (equipment, personnel, etc.) and methods that will be required to perform system verification and validation and allow project leadership to estimate the duration of verification and validation activities.

3.4.5 The validation plans shall include the integration or project phase of each activity.

3.4.6 Requirements may be verified/validated strategically at several different points in a project lifecycle to reduce risk of noncompliance of the complete system.

3.4.7 Each requirement shall have acceptance criterion, and tolerances where applicable.

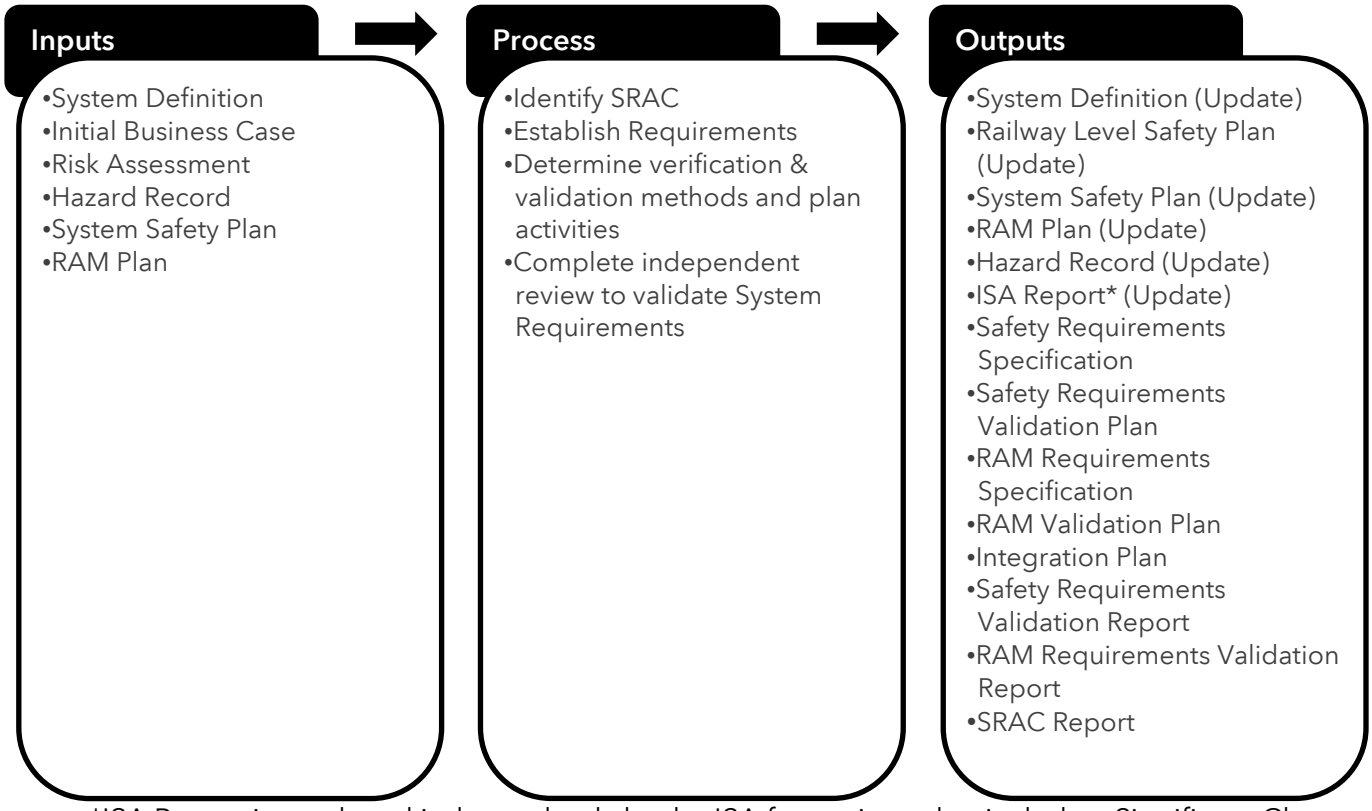
3.4.8 Each requirement shall have a rationale that states its intent, justifies its inclusion, any assumptions and the methods used to determine acceptance criteria.

3.4.9 Requirements shall be written to conform to best practices. (clear, accurate, complete, singular, achievable, unambiguous, free of grammatical/spelling errors, able to be verified/validated, free of implementation specifics, free of contradictions… etc.)

3.4.10 The validation plans shall state how each requirement will be validated. Each requirement will be validated by review of design, analysis, inspection, testing or a combination of methods if necessary.

3.4.11 Upon completion of the RAM and Safety System Requirements Specifications, the requirements shall be independently reviewed for quality and completeness. The findings of the reviews will be detailed in the Safety Requirements Validation Report and the RAM Requirements Validation Report. The intent of this review is to ensure that the correct requirements have been specified to ensure the original project objectives will be met by the design.

3.4.12 The requirements specifications are expected to require updating based on the Requirements Validation Reports.



*ISA Report is produced independently by the ISA for projects that include a Significant Change

3.5 Phase 5 - Architecture and Apportionment of System Requirements

3.5.1 The goal of this phase is to establish a system architecture that satisfies the requirements established in phase 4. This includes defining subsystems and interfaces to ensure all elements of the system (people, processes and equipment) function together.

3.5.2 Previous deliverables are expected to require updates as the design matures.

3.5.3 The System Definition must be updated to describe the system architecture and subsystems

3.5.4 Each subsystem requirement shall have acceptance criterion, and tolerances where applicable.

3.5.5 Each subsystem requirement shall have a rationale that states its intent, justifies its inclusion, any assumptions and the methods used to determine acceptance criteria.

3.5.6 Traceability of system requirements to subsystem requirements shall be documented & maintained, to ensure any subsequent revisions to requirements are properly implemented.

3.5.7 Interface requirements shall be identified, documented and maintained to ensure system elements function properly.

3.5.8 Analyses used to develop requirements shall be referenced as part of the requirement rationale. (e.g. Safety analyses, hazard analyses, RAM analysis, critical timing analysis etc.).

3.5.9 The integration, verification and validation activities for the RAM and Safety Subsystem Requirements shall be added to the Integration Plan, RAM Validation plan and Safety Validation Plans.

3.5.10 The RAM Analysis Process is prepared to determine the methods that will be used to assess the Reliability, Availability and Maintainability of the system design.

3.5.11 The Hazard Analysis Report is prepared to document the Hazard Analysis Activities.

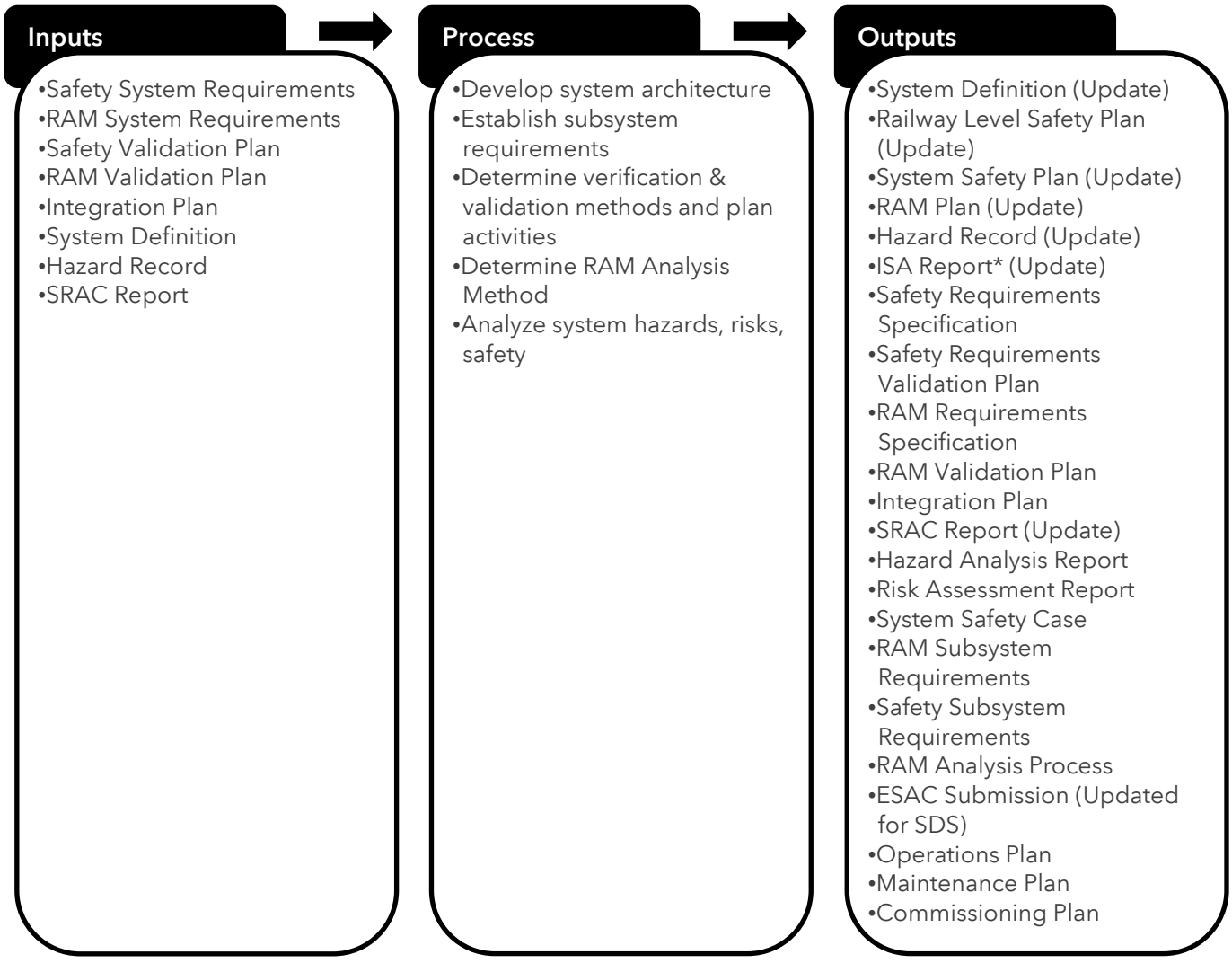
3.5.12 Risk Assessment Report is prepared to demonstrate the identified risks have been controlled.

3.5.13 System Safety Case is prepared to demonstrate that the design is complete, and safety requirements are mitigating the project hazards.

3.5.14 The completion of this phase is marked by the System Design Safety Review Gate (also referred to as System Design Safety Review Gate) where the work-to-date will be reviewed for acceptance. The review process is described in Section 4.

3.5.15 The ESAC Submission is updated to support the SDS Review

3.5.16 Design requirements shall be fully documented, and version controlled before the System Design Safety Review Gate. Revisions to design requirements after the System Design Safety Review gate shall be managed as per MX-SEA-STD-007



*ISA Report is produced independently by the ISA for projects that include a Significant Change

3.6 Phase 6 - Design and Implementation

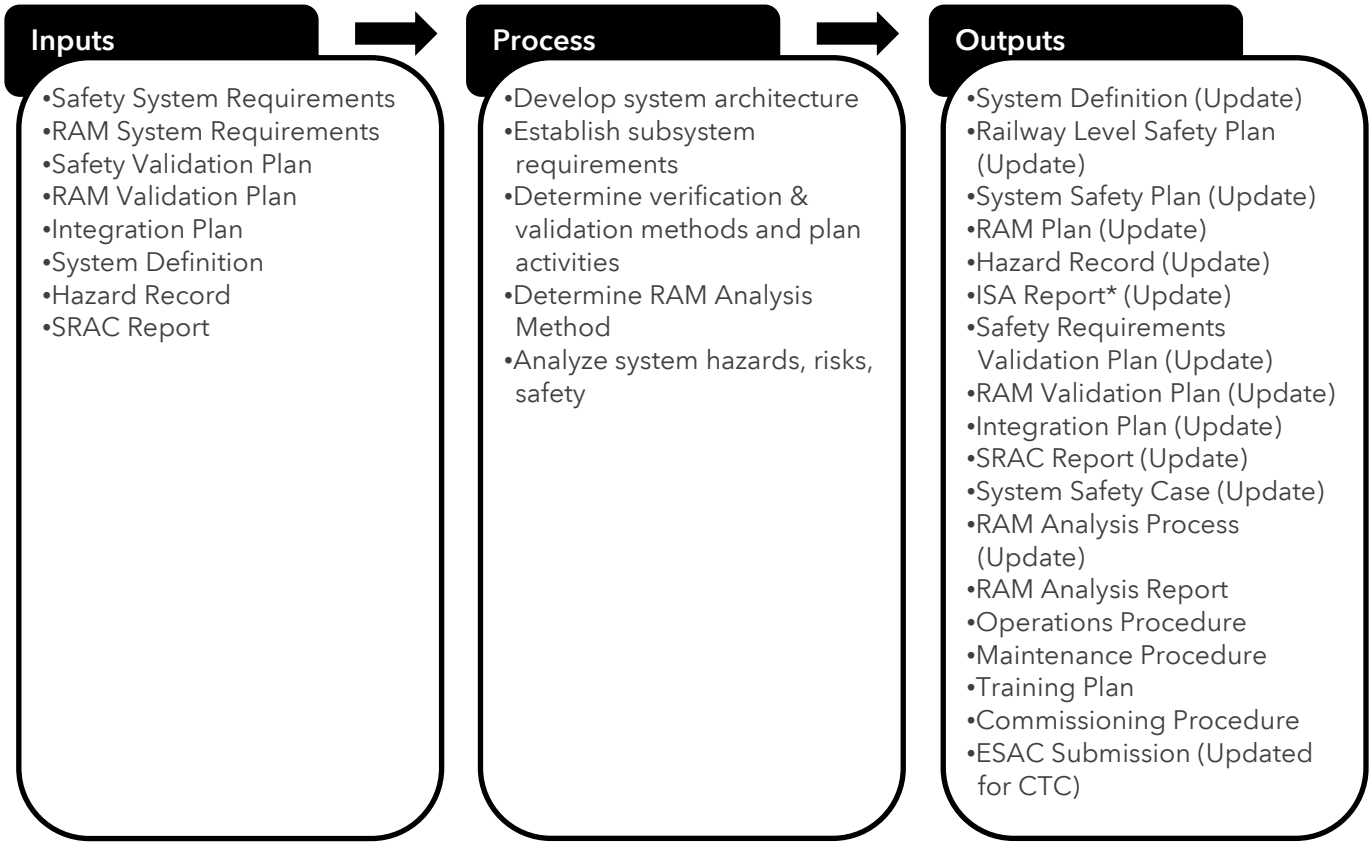
3.6.1 The goal of the design phase is to develop a system that complies with the established requirements. Activities include the design of physical assets as well as developing procedures for operations, maintenance, and commissioning. Upon completion of this phase the project team should have a complete understanding of the people, processes and equipment that compose the system.

3.6.2 During the design phase the RAM analysis shall be completed, and a report will be prepared.

3.6.3 It is expected that the design of the system will be revised based on the results of the RAM analysis.

3.6.4 At the end of the design phase the Consent to Construct review will occur prior to the manufacture & procurement of physical assets.

3.6.5 The ESAC Submission is updated to support the CTC Review



*ISA Report is produced independently by the ISA for projects that include a Significant Change

3.7 Phase 7 - Manufacture

3.7.1 The goal of the manufacturing phase is to complete the fabrication and procurement of physical assets while ensuring that the system analyses and documentation are updated to ensure accuracy.

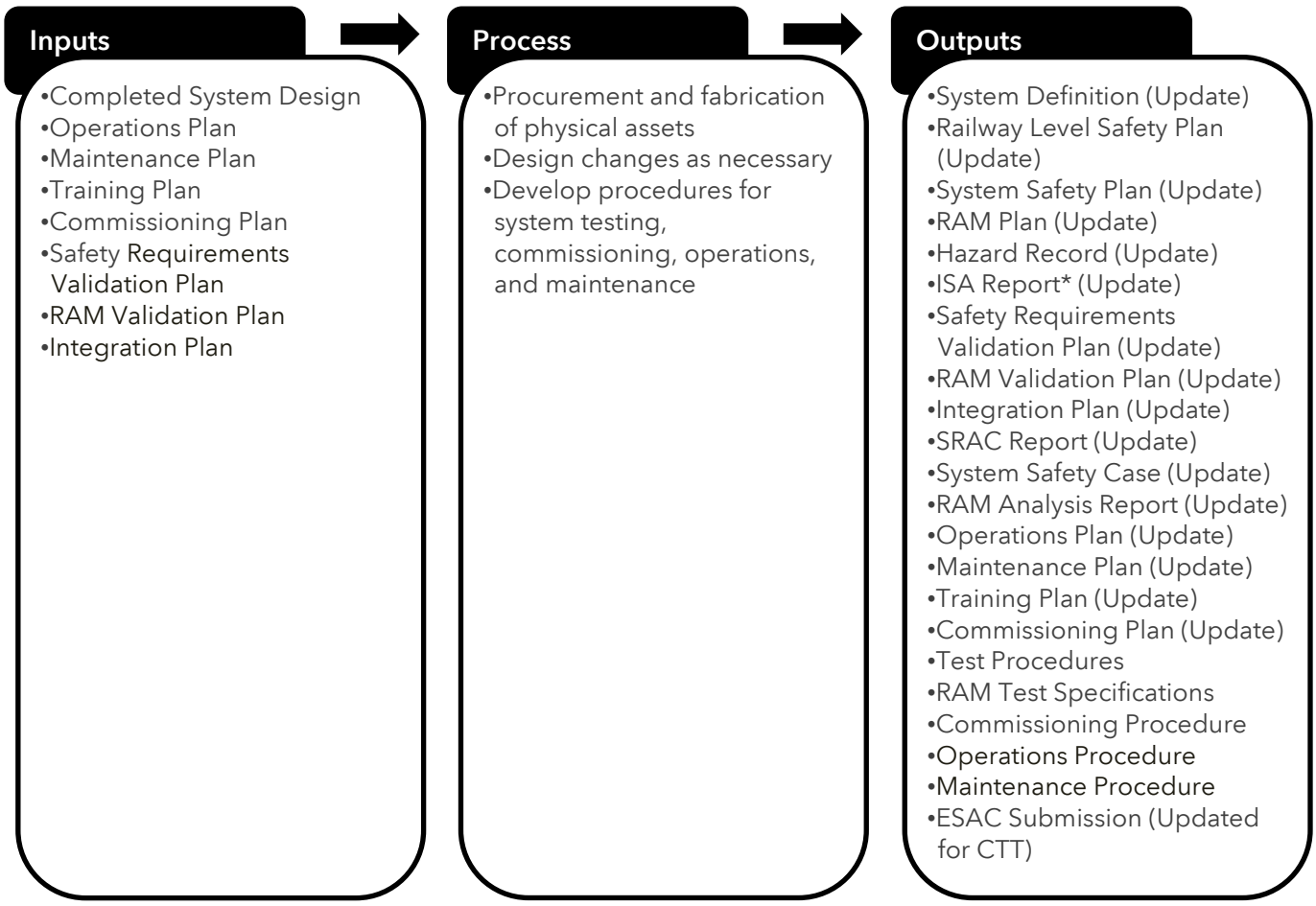
3.7.2 It is expected that unit level testing and inspections may occur during this phase as required by the project or manufacturer's Quality Plan, or as specified in the project's integration, commissioning or validation plans. (e.g. factory acceptance testing, inspections, etc.)

3.7.3 Test specifications are prepared to support the development of test procedures.

3.7.4 Procedures for testing, (e.g. factory acceptance testing, site integration testing and site acceptance testing) commissioning, training, operations and maintenance are prepared.

3.7.5 At the end of this phase the Consent to Test Review Gate will occur to ensure that the equipment and documentation is acceptable to proceed with testing.

3.7.6 The ESAC submission is updated to support the CTT Review.



*ISA Report is produced independently by the ISA for projects that include a Significant Change

3.8 Phase 8 - Integration

3.8.1 The goal of the integration phase is to assemble and install the complete system and demonstrate that the complete system functions as intended and meets the Safety and RAM requirements.

3.8.2 FRACAS shall be implemented during this phase to collect data during test activities.

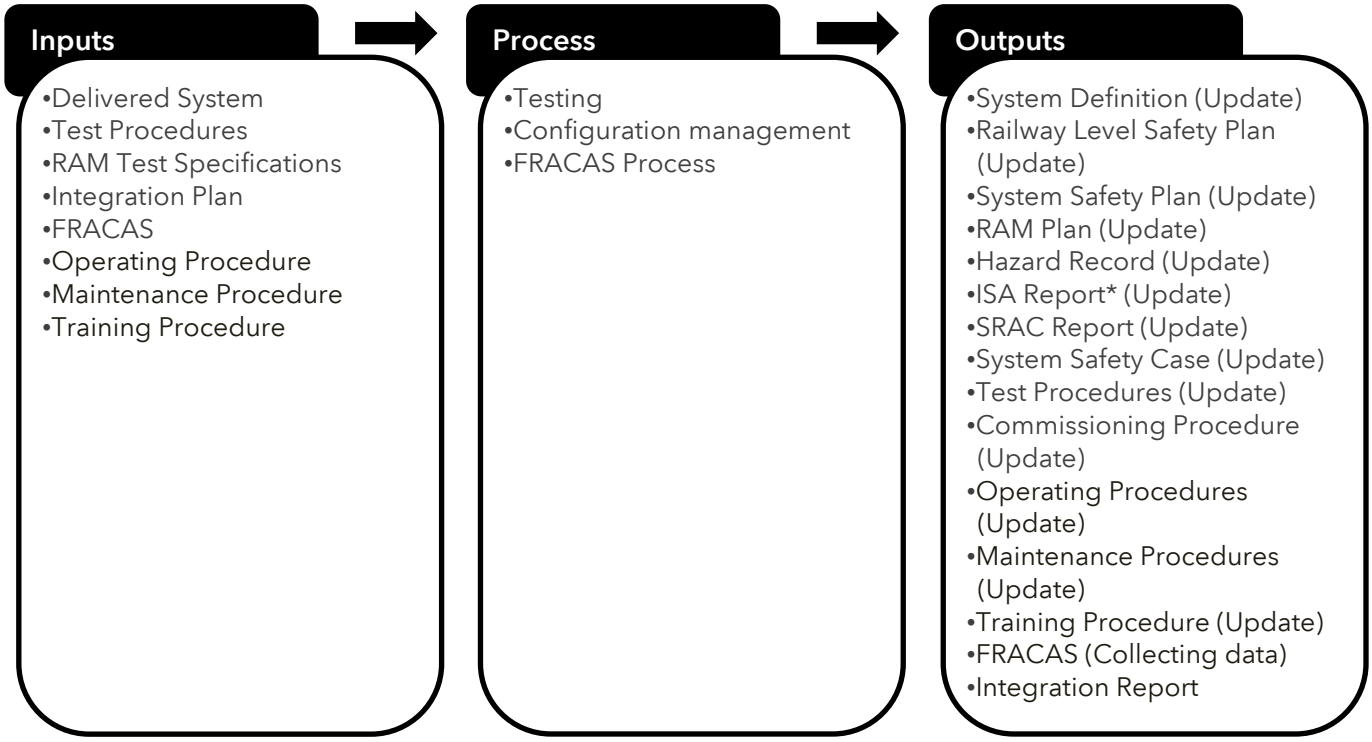
3.8.3 Documentation of design issues discovered during the integration and test process shall be managed using a configuration management process. This includes issues related to new and legacy assets, software, procedures and processes.

3.8.4 Integration and test activities will be carried out as per the integration plan.

3.8.5 Prepare Integration Report to document integration activities and resolution of any discovered issues.

3.8.6 Verification and Validation activities shall only be performed once the subsystem or system being verified or validated is in a stable, documented configuration.

3.8.7 The configuration, including version, serial numbers, of all physical assets, production software, procedures, analysis software, and measurement tools utilized for verification and validation activities shall be documented in the validation report.



*ISA Report is produced independently by the ISA for projects that include a Significant Change

3.9 Phase 9 - System Validation

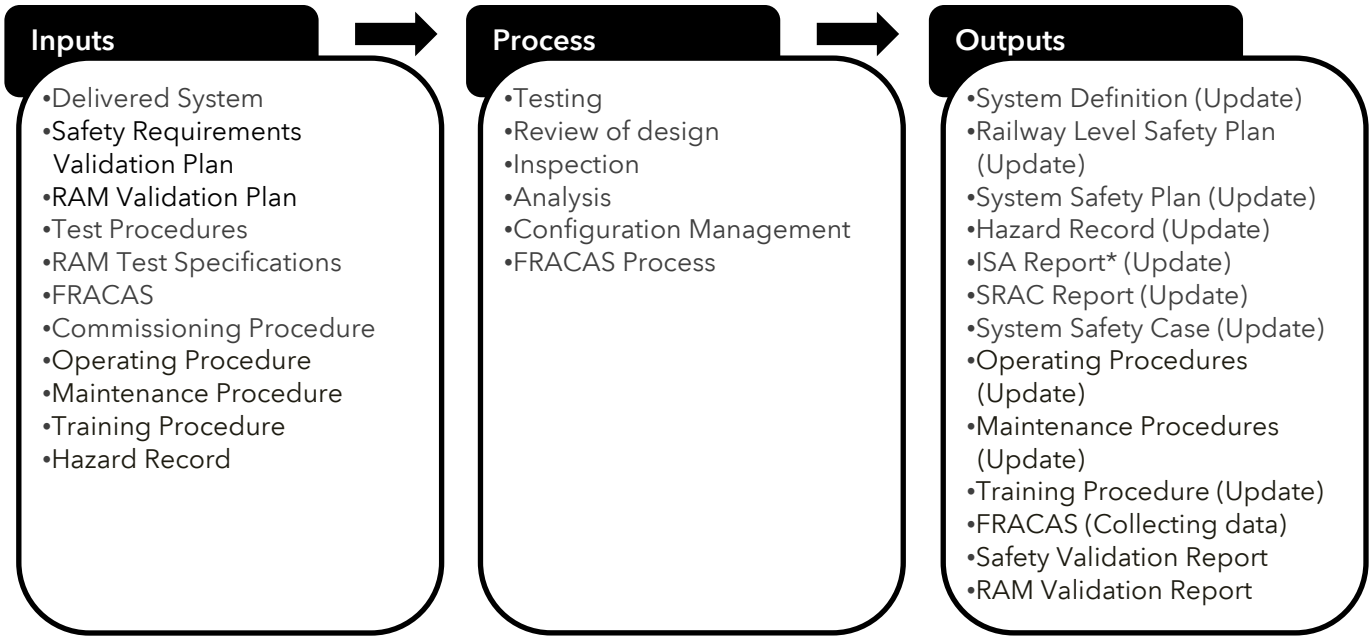
3.9.1 The goal of the Validation Phase is to determine, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled.

3.9.2 Validation activities shall be performed and documented as per the Validation Plans and approved test procedures.

3.9.3 Deviations from the validation plan shall be recorded and justified.

3.9.4 The configuration, including version, serial numbers, of all physical assets, production software, procedures, analysis software, and measurement tools utilized for verification and validation activities shall be documented in the validation report.

3.9.5 Confirm or update the safety case based on the results of the validation activities.



*ISA Report is produced independently by the ISA for projects that include a Significant Change

3.10 Phase 10 - System Acceptance

3.10.1 The goal of the acceptance phase is to assess the compliance and quality of the system based on the supporting evidence in the Validation Reports and System Safety Case.

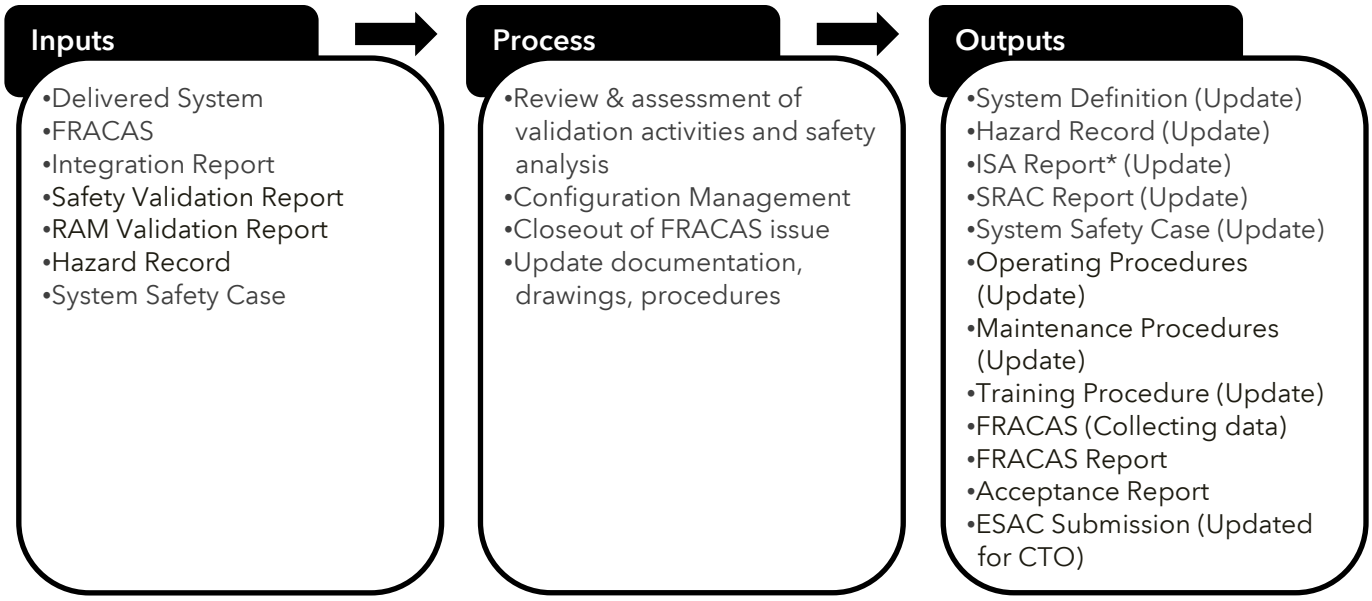
3.10.2 If accepted, ownership of the system would transfer to the organization responsible for operating and maintaining the system.

3.10.3 Closeout of open issues. (e.g. All drawing and procedure updates are completed, Defects are resolved and validated, remaining defects are mitigated by the safe operating restrictions (SOR), operational and maintenance manuals are produced)

3.10.4 Transfer FRACAS data and any open issues to operations for resolution. (e.g. minor issues that do no impact acceptability of the delivered system, interface issues that can only be addressed by the operations groups)

3.10.5 The Systems Acceptance phase ends with the Consent to Operate review gate.

3.10.6 The ESAC submission is updated and the System Safety Case is finalized to support the CTO Review.



*ISA Report is produced independently by the ISA for projects that include a Significant Change

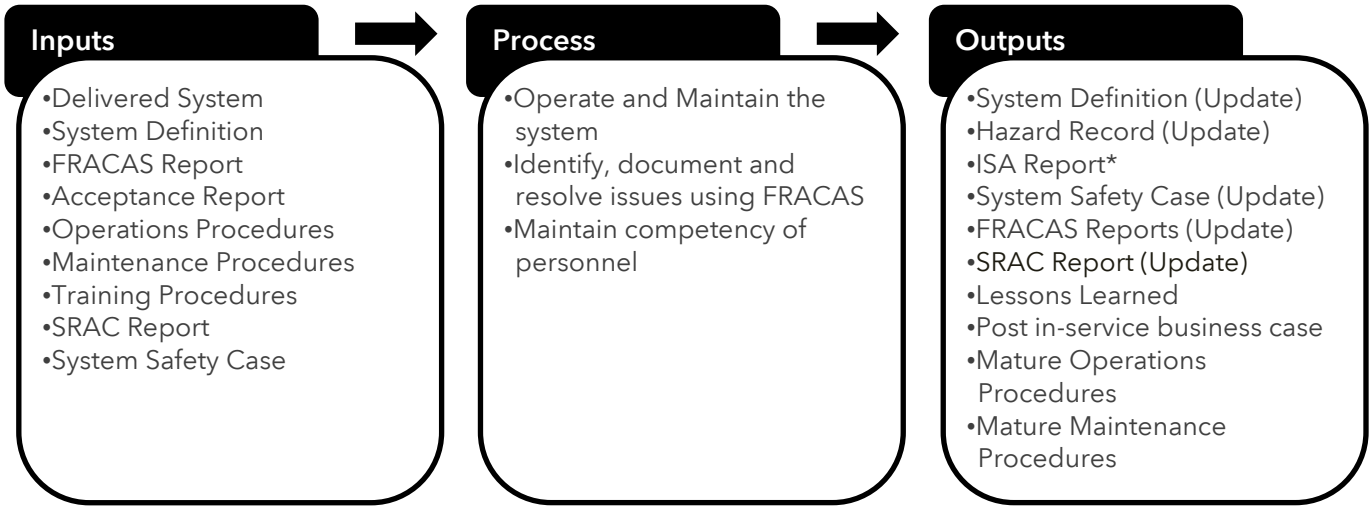
3.11 Phase 11 - Operation, Maintenance & Performance Monitoring

3.11.1 The goal of the operation, maintenance & performance monitoring phase is to ensure the system maintains compliance with RAMS requirements.

3.11.2 Identified issues shall be documented and resolved through FRACAS.

3.11.3 Changes to the system shall be controlled through the responsible engineering organization.

3.11.4 Changes to the system may require the safety case, or risk assessment to be revisited and/or testing before full adoption.



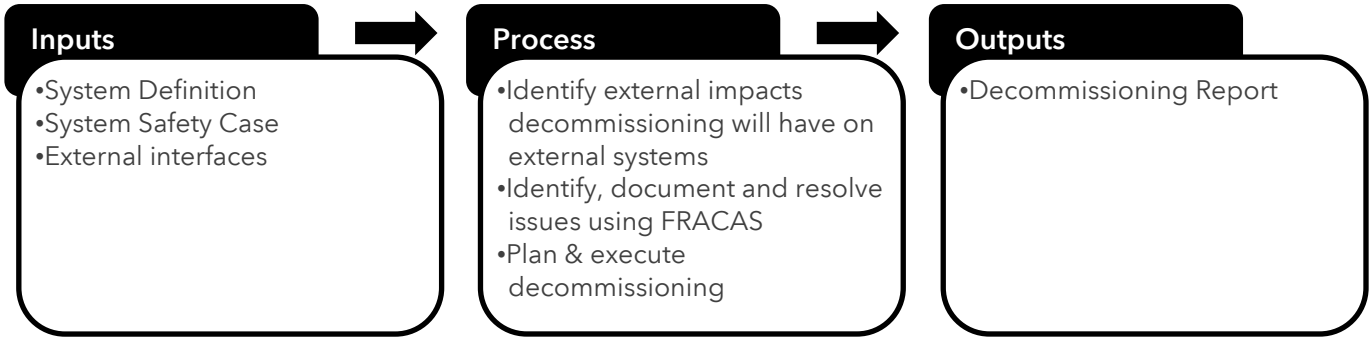
*ISA Report is produced independently by the ISA for projects that include a Significant Change

3.12 Phase 12 - Decommissioning

3.12.1 The goal of the decommissioning phase is to ensure that the decommissioning and disposal of the system is safely completed.

3.12.2 Identify any RAMS impacts decommissioning will have to external systems.

3.12.3 Develop and execute a decommissioning plan to ensure tasks are completed safely and do not unnecessarily disrupt external systems.



4. RAMS Design Reviews

4.1 Approval in Principle

4.1.1 The Approval In Principle (AIP) gate covers phases 1 (Concept), 2 (System Definition) and 3 (Risk Analysis) of the RAMS lifecycle from EN 50126. These initial phases represent the planning and development phase of the project where the contracted project is defined, and risk evaluation and assessment commences.

4.1.2 Metrolinx shall be responsible for completing the AIP Phase and AIP Gate prior to entering into any contracts with the project company in order to define the project and the project requirements.

4.1.3 If AFP procurement is used, then the AIP activities, including the AIP Gate, shall be repeated by the contracted vendor. This work by the vendor may be part of the bid preparation and may be included in the bid evaluation.

4.1.4 The AIP Review must be completed before IP Stage 2 (development). For AFP the AIP may be repeated during the early part of the development phase.

4.1.5 The Engineering Safety and Assurance Case (ESAC) Submission integrates all safety activities, system engineering lifecycle phase activities including RAMS analyses, CMREA activities and Product Assurance activities. Its purpose is to ensure that the documentation at the AIP gate forms a consistent baseline. The Approval In Principle Submission shall be reviewed by the contracted project's ISA who shall produce an ISA report.

4.1.6 The Approval in Principle deliverables shown in the AIP column of Table 5 shall be prepared and submitted to the Secretary of the System Review Panel (SRP).

4.1.7 Many of the documents included in the submission are iterative and at the AIP gate it is not expected that they are fully developed. The information referenced in guidance documents, product description documents and templates specify the minimum amount of information

in each document to pass the review gate. Additional details/information shall be included as necessary and when available.

4.2 System Design Safety

4.2.1 The System Design Safety (SDS) gate covers Phases 4 (Design Requirements), and 5 (Architecture and Apportionment of System Requirements) of the RAMS lifecycle from EN 50126.

4.2.2 The System Design Safety review was previously called the Single Design Solution Review. The two terms are considered interchangeable.

4.2.3 The detailed system requirements shall be version controlled leading into the System Design Safety gate.

4.2.4 The SDS Review must be completed before IP Stage 3 (design)

4.2.5 The primary goal of the SDS Gate is to review the detailed RAMS requirements and determine if the proposed system architecture can meet said requirements.

4.2.6 As part of the design documentation, the solutions that were considered but were not selected shall be recorded along with the reasoning for selecting the preferred solution.

4.2.7 The System Design Safety deliverables shown in the SDS column of Table 5 shall be prepared and submitted to the Secretary of the SRP.

4.2.8 The review of the System Safety Case and Hazard Record will focus on ensuring that the hazards are sufficiently documented and controlled.

4.2.9 The review of the Integration and Validation Plans will focus on ensuring that the integration and validation strategy is adequate to reduce risk and provide sufficient evidence of compliance.

4.2.10 Any document updates required as a result of the review shall be revision controlled and documented.

4.3 Consent to Construct

4.3.1 The Consent to Construct (CTC) gate covers Phase 6 (Design and Implementation) of the RAMS lifecycle from EN 50126

4.3.2 The primary goal of the Consent to Construct Gate is to review the detailed design of the system before it is manufactured to ensure it can meet the design requirements. Resolving issues before manufacture is significantly more efficient and cost effective than correcting an issue after it has been manufactured.

4.3.3 The CTC Review must be completed before IP Stage 4 (build)

4.3.4 The Consent to Construct deliverables shown in the CTC column of Table 4 shall be prepared and submitted to the Secretary of the SRP.

4.3.5 With the detailed design of the system complete, the Operation, Maintenance, Commissioning and Training Plans are reviewed to ensure that people, process and technology all function together

4.3.6 The RAM Analysis Report is prepared to determine if the designed system can meet the RAM requirements.

4.3.7 The updated Hazard Record and Safety Case are reviewed to ensure they reflect the detailed design of the system and that the risk profile of the system is still acceptable.

4.4 Consent to Test

4.4.1 The Consent to Test (CTT) gate covers Phase 7 (Manufacturing) of the RAMS lifecycle from EN 50126.

4.4.2 The primary goal of the Consent to Test gate is to ensure that the system is tested in a safe and deliberate manner.

4.4.3 The CTT Review must be completed during IP Stage 4 (build), before system testing begins

4.4.4 The Consent to Test deliverables shown in the CTT column of Table 4 shall be prepared and submitted to the Secretary of the SRP.

4.4.5 All test procedures are reviewed for quality and content to ensure that the requirements are satisfied.

4.4.6 FRACAS and configuration management must be in place before testing can occur.

4.5 Consent to Operate

4.5.1 The Consent to Operate (CTO) gate covers phase 8 (Integration), phase 9 (System Validation), and phase 10 (Acceptance) of the RAMS lifecycle from EN 50126.

4.5.2 The primary goal of the Consent to Operate gate is to ensure that sufficient testing, inspection, review and analysis of the system has been completed and documented to prove compliance with the RAMS requirements.

4.5.3 The CTO Review must be completed before IP Stage 5 (Operate)

4.5.4 The Consent to Operate deliverables shown in the CTO column of Table 4 shall be prepared and submitted to the Secretary of the SRP.

4.5.5 Open issues, risks and assumptions must be documented. If the open issues, risks, and assumptions are unacceptable then they will need to be addressed to achieve system acceptance.

4.5.6 All design documentation, procedures, and training materials must be finalized and submitted to Metrolinx.

Appendix B Deliverables & Documentation

B.1 RAMS Deliverables Descriptions

RAMS Deliverable	Description
Acceptance Report	The Acceptance Report summarizes the compliance of the system with the design requirements, all open risks, hazards, assumptions and issues that Metrolinx will become responsible for upon system acceptance.
Commissioning Plan	The Commissioning Plan details the activities and resources required to commission the system. The goal of a commissioning is to demonstrate system compliance with requirements under the same conditions that the system would be subject to during normal use.
Commissioning Procedure	Commissioning Procedures document the detailed step-by-step instructions to be followed during a commissioning activity. The goal of a commissioning is to demonstrate system compliance with requirements under the same conditions that the system would be subject to during normal use.
Engineering Safety and Assurance Case (ESAC)	The ESAC submissions summarize the key evidence that the system is safe, operable, maintainable and meets functional, interface/integration, business, performance and operational requirements to ensure that the documentation at each gate forms a consistent baseline.
FRACAS	Failure Reporting Analysis and Corrective Action System (FRACAS) is a process that collects equipment failure data so it can be analyzed to identify and monitor solutions and improvement opportunities.
FRACAS Report	The FRACAS Report summarizes all failures that occurred while the system was being tested, the corrective actions taken, and how those corrective actions have impacted system performance.
Hazard Analysis Report	The Hazard Analysis Report documents the Hazard Analysis Activities performed to support a Risk Assessment. Hazard Analysis is the process of identifying hazards and analysing their causes, and the derivation of requirements to limit the likelihood and consequences of hazards to a tolerable level.
Hazard Record	The Hazard Record forms the basis for ongoing risk management for safety. It represents a tool to identify, track and manage hazards and their closure in accordance with the requirements of the Canadian Method for Risk Evaluation and Assessment for Railway Systems (CMREA) and EN 50126:2017.
Integration Plan	The Integration Plan documents the activities and resources required to confirm functionality of the system. The plan includes strategy and sequence that subsystems will be tested and connected to interfacing systems, until the system is fully integrated.

RAMS Deliverable	Description
Integration Report	The Integration Report documents the results of the activities defined in the Integration Plan.
ISA Plan	The ISA plan details the safety assessment activities to be performed by the project Independent Safety Assessor.
ISA Report	The Independent Safety Assessor (ISA) Report (also known as the ISA ESAC Report) describes the independent safety assessment activities and their conclusions. ISA activities provide additional confidence about the avoidance, mitigation or acceptance of systematic failures that can impact safety.
Maintenance Plan	The Maintenance Plan defines the impact the proposed change has on the maintenance of the railway system and details how this change shall be implemented.
Maintenance Procedure	A Maintenance Procedure provides detailed instruction on how to perform a particular maintenance activity. The Maintenance Procedures include all the relevant information required to maintain the railway system safely and reliably and to enable compliance with RAMS requirements to be maintained.
Operations Plan	The Operations Plan defines the impact the proposed change has on the operation of the railway system and details how this change will be implemented.
Operations Procedure	An Operations Procedure provides detailed instruction on how to perform a particular operating activity. The Operations Procedures include all the relevant information required to operate the railway system safely and reliably and to enable compliance with RAMS requirements to be maintained.
Preliminary Railway Level System Definition	The Preliminary Railway Level System Definition captures the high-level scope of the planned changes to the railway and identifies all works associated with the defined scope and determines if the change is considered significant risk as per CMREA. It is used to describe large-scale program level changes to the railway, which are divided into two or more projects described in “Preliminary System Definition” documents.
Preliminary Safety Case	The Preliminary Safety Case provides evidence of how the system under consideration is safe to proceed through the Approval in Principle (AIP) Gate. It details all system safety hazards identified in the early project lifecycle phases (i.e., Phase 1 to 3), mitigation measures and residual risks to be managed by the residual risk owner.
Preliminary System Definition	The Preliminary System Definition captures the high-level scope of the project and determines if the project is considered a Significant Change as per CMREA. The significance decision and justification are documented as part of the Preliminary System Definition.

RAMS Deliverable	Description
Railway Level Safety Plan	The Railway Level Safety Plan defines the high-level System Safety Management (SSM) activities that shall take place throughout the lifecycle of the project from Phase 2 through to Phase 10, to be followed by projects. It is used for large program level changes to the railway, which are divided into two or more projects each of which will have a "System Safety Plan".
RAM Analysis Process	The RAM analysis Process describes the methods that will be used to assess the Reliability, Availability and Maintainability of the system design. The analysis models the systems, subsystems and equipment, where applicable, and helps identify the failures and their effects on the overall reliability of the relevant equipment.
RAM Analysis Report	The RAM Analysis Report documents the results of the RAM Analysis activities that were performed in accordance with the RAM Plan. These activities are performed to determine if the system can meet the RAM requirements before construction.
RAM Plan	The RAM Plan describes the project RAM activities, including the project RAM Policy, timescales and resources needed to satisfy RAM requirements relevant to the project.
RAM Requirements Specification	The RAM Requirements Specification establishes the RAM related design requirements of the system, and how the requirements are apportioned to subsystems. It also documents the context and rationale considered during requirement development. The requirements form an agreement among the project team and Metrolinx, providing a clear shared vision of the attributes of the system and criteria for acceptance.
RAM Requirements Validation Report	The RAM Requirements Validation Report documents an independent review of the RAM Requirements to confirm that the specified requirements will meet the project objective and are free of errors, and omissions.
RAM Subsystem Requirements	The RAM Subsystem Requirements Specification establishes the RAM related design requirements of a subsystem. It also documents the context and rationale considered during requirement development and traceability to system level requirements. The requirements form an agreement among the project team and Metrolinx, providing a clear shared vision of the attributes of the subsystem and criteria for acceptance.
RAM Test Specification	RAM Test Specifications provide detailed instruction on how to perform a particular RAM test activity. It includes all the relevant information required to perform the test.
RAM Validation Plan	The RAM Validation Plan documents a set of activities, resources and events that demonstrate system compliance with RAM requirements.
RAM Validation Report	The Reliability, Availability and Maintainability (RAM) Validation Report documents the activities that took place to demonstrate compliance with the RAM requirements and details the result of the validation.

RAMS Deliverable	Description
Risk Assessment Report	Risk Assessment Report is to document RAMS risk assessment activities that are not included in the Hazard Analysis Report. This can include risks that do not have safety implications or risks that require more detailed analysis than what is practical to include in the Hazard Record or Hazard Analysis Report. A Risk Assessment Report allows for more details to be documented and are referenced in the Hazard Record and/or the RAM analysis.
Safety Related Application Conditions	The Safety Related Application Conditions are the conditions which need to be met for a system to be safely integrated and safely operated. The document describes the identification process for SRACs, status of each SRAC (i.e., whether the SRAC has been fulfilled), and the process that was undertaken by the project team to reach a decision on that status. It shall include evidence, or links to evidence, to prove the SRACs have been fulfilled, if they are unfulfilled how they will be handled or carried forward to the next stage or high-level system.
Safety Requirements Specification	The Safety Requirements Specification establishes the safety related design requirements of the system, and how the requirements are apportioned to subsystems. It also documents the context and rationale considered during requirement development. The requirements form an agreement among the project team and Metrolinx, providing a clear shared vision of the attributes of the system and criteria for acceptance.
Safety Requirements Validation Report	The Safety Requirements Validation Report documents an independent review of the Safety Requirements to confirm that the specified requirements will meet the project objective and are free of errors, and omissions.
Safety Subsystem Requirements	The Safety Subsystem Requirements Specification establishes the Safety related design requirements of a subsystem. It also documents the context and rationale considered during requirement development and traceability to system level requirements. The requirements form an agreement among the project team and Metrolinx, providing a clear shared vision of the attributes of the subsystem and criteria for acceptance.
Safety Validation Plan	The Safety Validation Plan documents a set of activities, resources and events that demonstrate system compliance with safety requirements.
Safety Validation Report	The Safety Validation Report documents the activities that took place to demonstrate compliance with the Safety requirements and details the result of the validation.
System Definition	The System Definition describes the essential characteristics and functions of the system and clarifies the interfaces and boundaries to other systems including the input to be provided and the output that can be expected. The System Definition influences the System Safety Plan and the Reliability, Availability and Maintainability (RAM) Plan and defines the scope of the system hazard and risk analyses.
System Safety Case	The System Safety Case consists of the documented structured safety justification which provides evidence of how the system under consideration is safe for operations. It details all system safety hazards identified through the project lifecycle, mitigation measures and residual risks to be managed by the residual risk owner.

RAMS Deliverable	Description
System Safety Plan	The System Safety Plan describes the project safety activities, including timescales and resources, to satisfy safety requirements relevant to the project.
Test Procedures	Test Procedures document the detailed step-by-step instructions to be followed during a Test.
Training Plan	The Training Plan defines the training required for the staff impacted by the proposed change to the railway system.
Training Procedure	The Training Procedure describes what competence the trainees will learn at the end of a particular training module. It includes all the relevant information required for training of staff who will operate or maintain the railway system and to enable compliance with RAMS requirements to be maintained.

B.2 RAMS Deliverables Schedule

P-Preliminary: An uncontrolled mature draft that is expected to change based on the results of other activities

F-Final: A complete version-controlled document that may not require updates.

U-Updated: A complete version-controlled document that has been updated due to new information.

TABLE 5 RAMS DELIVERABLES SCHEDULE

RAMS Deliverable	SEA/RAMS Phase	1	2	3	AIP	4	5	SDS	6	CTC	7	CTT	8	9	10	CTO	11	12
Preliminary Railway System Definition		F			**F**													
Preliminary System Definition		F			**F**													
ISA Plan[3]		F			**F**													
System Definition			P	F	**F**	U	U	**U**	U	**U**	U	**U**	U	U	U	**U**	U	
Railway Level Safety Plan			P	F	**F**	U	U	**U**	U	**U**	U	**U**	U	U				
System Safety Plan			P	F	**F**	U	U	**U**	U	**U**	U	**U**	U	U				
RAM Plan			P	F	**F**	U	U	**U**	U	**U**	U	**U**	U					
Hazard Record				F	**F**	U	U	**U**	U	**U**	U	**U**	U	U	U	**U**	U	
Risk Assessment				F	**F**													
ISA Report[3]				F	**F**	U	U	**U**	U	**U**	U	**U**	U	U	U	**U**	U	
Preliminary Safety Case				F	**F**													
ESAC Submission					**F**			**F**		**F**		**F**				**F**		
Safety Requirements Specification				P		P	F	**F**										
Safety Validation Plan						P	F	**F**	U	**U**	U	**U**						
RAM Requirements Specification						P	F	**F**										
RAM Validation Plan						P	F	**F**	U	**U**	U	**U**						
Integration Plan						P	F	**F**	U	**U**	U	**U**						
Safety Requirements Validation Report					P	F		**F**										
RAM Requirements Validation Report						F		**F**										
Safety Related Application Conditions						F	U	**U**	U	**U**	U	**U**	U	U	U	**U**	U	
Hazard Analysis Report							F	**F**										
Risk Assessment Report							F	**F**										
System Safety Case							F	**F**	U	**U**	U	**U**	U	U	U	**U**		
RAM Subsystem Requirements							F	**F**										

[3] Only required for Significant Changes as per CRMEA Risk Assessment

RAMS Deliverable	SEA/RAMS Phase	1	2	3	AIP	4	5	SDS	6	CTC	7	CTT	8	9	10	CTO	11	12
Safety Subsystem Requirements							F	**F**										
RAM Analysis Process							F	**F**	U									
RAM Analysis Report									F	**F**	U	**U**						
Operations Plan							F	**F**	U	**F**	U	**U**						
Maintenance Plan							F	**F**	U	**F**	U	**U**						
Training Plan									F	**F**	U	**U**						
Commissioning Plan							F	**F**			U	**U**						
Test Procedures											F	**F**	U					
RAM Test Specification											F	**F**						
Commissioning Procedure									F	**F**		**F**	U					
Operations Procedure									F	**F**		**F**	U	U	U	**U**	U	
Maintenance Procedure									F	**F**		**F**	U	U	U	**U**	U	
Training Procedure											F	**F**	U	U	U	**U**	U	
FRACAS												**F**	U	U	U	**U**	U	U
Integration Report													F			**F**		
Safety Validation Report														F		**F**		
RAM Validation Report														F		**F**		
FRACAS Report															F	**F**	U	U
Acceptance Report															F	**F**		

B.3 RAMS Deliverables Supporting Documentation

Standard: Overarching governing document that describes a process, how different specific deliverables and activities interact and fit within the project lifecycle.

Product Description: Provide specific requirements for an activity including its intent, required information, and the required report sections.

Guidance Document: Supporting material for preparing specific deliverables. Guidance documents contain best practices, examples, writing prompts, and general advice on how to approach each activity. The guidance document follows the structure of the template, reiterates the intent of each section and may repeat specific requirements described in Product Descriptions for context and to provide additional rationale, explanation and guidance.

Template: Provides preferred document format and structure.

TABLE 6 RAMS DOCUMENTATION

Initial Delivery	Deliverable	Standard	Product Description	Guidance Document	Template
Project Governance	IDR Process Standard	MX-SEA-STD-200			
	Metrolinx IDR Plan		MX-SEA-PD-201	MX-SEA-GDC-201	MX-SEA-TPL-201
	Metrolinx Stakeholder Plan		MX-SEA-PD-202	MX-SEA-GDC-202	MX-SEA-TPL-202
Technical Governance	FMECA	MX-SEA-STD-002			
	RCA (Root Cause Analysis) Process	MX-SEA-STD-004			
	RAM V&V (Verification and Validation) Process	MX-SEA-STD-005			
	Requirements Management	MX-SEA-STD-007			
1	Preliminary Railway System Definition		MX-SEA-PD-104	MX-SEA-GDC-104	MX-SEA-TPL-104
1	Preliminary System Definition		MX-SEA-PD-105	MX-SEA-GDC-105	MX-SEA-TPL-105
1	ISA Plan	TBD			
2	System Definition		MX-SEA-PD-106	MX-SEA-GDC-106	MX-SEA-TPL-106
2	Railway Level Safety Plan	TBD			
2	System Safety Plan	TBD			
2	RAM Plan	MX-SEA-STD-003	MX-SEA-PD-119	MX-SEA-GDC-119	MX-SEA-TPL-119
3	Hazard Record	TBD			
3	ISA Report	TBD			
3	Preliminary Safety Case	TBD			
3	ESAC	TBD			
4	Safety Requirements Specification		MX-SEA-PD-112	MX-SEA-GDC-112	MX-SEA-TPL-112
4	Safety Requirements Validation Plan	TBD			

4	RAM Requirements Specification		MX-SEA-PD-121	MX-SEA-GDC-121	MX-SEA-TPL-121
4	RAM Validation Plan		MX-SEA-PD-123	MX-SEA-GDC-123	MX-SEA-TPL-123
4	Integration Plan		MX-SEA-PD-132	MX-SEA-GDC-132	MX-SEA-TPL-132
4	Safety Requirements Validation Report	TBD			
4	RAM Requirements Validation Report		MX-SEA-PD-138	MX-SEA-GDC-138	MX-SEA-TPL-138
4	Safety Related Application Conditions	TBD			
5	Hazard Analysis Report	TBD			
5	Risk Assessment Report	MX-SEA-STD-006	MX-SEA-PD-111	MX-SEA-GDC-111	MX-SEA-TPL-111
5	System Safety Case		MX-SEA-PD-115	MX-SEA-GDC-115	MX-SEA-TPL-115
5	RAM Subsystem Requirements		MX-SEA-PD-122	MX-SEA-GDC-122	MX-SEA-TPL-122
5	Safety subsystem requirements		MX-SEA-PD-140	MX-SEA-GDC-140	MX-SEA-TPL-140
5	RAM Analysis Process		MX-SEA-PD-117		
6	RAM Analysis Report		MX-SEA-PD-120	MX-SEA-GDC-120	MX-SEA-TPL-120
6	Operations Plan		MX-SEA-PD-127	MX-SEA-GDC-127	MX-SEA-TPL-127
6	Maintenance Plan		MX-SEA-PD-128	MX-SEA-GDC-128	MX-SEA-TPL-128
6	Training Plan		MX-SEA-PD-129	MX-SEA-GDC-129	MX-SEA-TPL-129
6	Commissioning Plan		MX-SEA-PD-130	MX-SEA-GDC-130	MX-SEA-TPL-130
7	RAM Test Specification		MX-SEA-PD-124	MX-SEA-GDC-124	MX-SEA-TPL-124
7	Commissioning Procedure		MX-SEA-PD-145		
7	Operations Procedure		MX-SEA-PD-142		
7	Maintenance Procedure		MX-SEA-PD-143		
7	Training Procedure		MX-SEA-PD-144		
8	FRACAS	MX-SEA-STD-001	MX-SEA-PD-126		
8	Integration Report		MX-SEA-PD-133	MX-SEA-GDC-133	MX-SEA-TPL-133
9	Safety Validation Report	TBD			
9	RAM Validation Report		MX-SEA-PD-125	MX-SEA-GDC-125	MX-SEA-TPL-125
10	Acceptance Report		MX-SEA-PD-131	MX-SEA-GDC-131	MX-SEA-TPL-131

Appendix C (Informative) Process Alignment

(Informative) Mapping between Metrolinx IP Stages, EN50126 Phases and System Engineering Process