



Metrolinx RAM V&V (Verification and Validation) Process

RAMS-5

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RAM V&V (Verification and Validation) Process

RAMS-5

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Preface

This is the first edition of the Verification and Validation process published as part of Metrolinx RAMS (Reliability, Availability, Maintainability and Safety) Standards. It describes the RAM Verification and Validation process throughout the system lifecycle and the main tasks and deliverables from concept phase to decommissioning phase.

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-ENG-PRC-001 | Procedure for Requesting Deviations to Metrolinx Standard Technical Requirements | Reference |
| CPG-QAT-FRM-106 | CPG Terms Glossary | Reference |
| RAMS-3 | RAM Plan Process | Reference |
| TBD | Roles and Responsibilities Matrix (RACI) for RAMS tasks | Document |

Acronyms and Abbreviations

TABLE 0-2 ACRONYMS AND ABBREVIATIONS

| Acronym | Full Name |
|---------|--|
| BU | Business Unit |
| CPG | Capital Projects Group |
| FMECA | Failure Modes, Effects and Criticality Analysis |
| FRACAS | Failure Reporting, Analysis and Corrective Action System |
| RACI | Responsible Accountable Consulted Informed |
| RAM | Reliability, Availability and Maintainability |
| RAMS | Reliability Availability Maintainability and Safety |
| SOGR | State of Good Repair |

Definitions

TABLE 0-3 TABLE OF DEFINITIONS

| Term | Definition | Source |
|---------------------|--|--|
| Acceptance criteria | A list of specific and defined conditions that must be met before a project has been considered completed and the asset/ system will be accepted by the Asset Class Teams. | |
| Approved Project | A project that has passed successfully through the investment panel stage gates and has approval to proceed with budget allocation. | <i>CPG-QAT-FRM-106, CPG Terms Glossary</i> |
| 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, Asset Data and Information Standards 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 |
| Assurance | Confidence in achieving a goal being pursued. Declaration intended to give confidence. | BS EN 50126:2017 |
| 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. | BS EN 50126:2017 |
| Compliance | state where a characteristic or property of a product, system or process satisfies the specified requirements | BS EN 50126:2017 |

| | | |
|------------------------------|--|--|
| Contractor | Could be: A Vendor; A Vendor which Metrolinx entered Contract with; A Vendor which will perform construction related work. | METROLINX PROCUREMENT SERVICES PROCEDURES AND PRACTICES April 25,2018 |
| Design | Activity applied in order to analyse and transform specified requirements into acceptable solutions. | BS EN 50126:2017 |
| Investment Panel (Metrolinx) | The Investment Panel ("IP") is management's ultimate accountable governance body for benefits management of business cases across the entire system lifecycle | Investment Panel ToR (03-1-2019) |
| Lifecycle | Series of identifiable stages through which an item goes, from its conception to disposal. | BS EN 50126:2017 |
| Like to Like Replacement | Replacing deteriorated asset with a similar asset in terms of type, specification and design. | NA |
| Maintainability | Ability to be retained in, or restored to, a state to perform as required, under given conditions of use and maintenance. | BS EN 50126:2017 |
| Planned Project | A project intended to go through the Investment Panel stage gates that is not yet approved to proceed and does not have budget approval. | <i>CPG-QAT-FRM-106, CPG Terms Glossary</i> |
| RAM plan | Documented set of time scheduled activities, resources and events serving to implement the organisational structure, responsibilities, procedures, activities, capabilities and resources that together ensure that an item will satisfy given RAM requirements relevant to a given contract or project. | BS EN 50126:2017 |
| Reliability | Ability to perform as required, without failure, for a given time interval, under given conditions. | BS EN 50126:2017 |
| Subsystem | Part of a system, which is itself a system | BS EN 50126:2017 |
| System | Set of interrelated elements considered in a defined context as a whole and separated from their environment | BS EN 50126:2017 |
| Tender | A Procurement Process, which can be issued via invitation or publicly advertised; is initiated through the issue of Procurement Documents which results in the submission of written offer(s) from Proponents to sell goods and/or services to Metrolinx, and where price is the determining factor of Award | METROLINX PROCUREMENT SERVICES PROCEDURES AND PRACTICES April 25,2018 |
| Validation | Confirmation through the provision of objective evidence, that the requirements for a specific | BS EN 50126:2017 |

| | | |
|---------------------|--|-------------------------|
| | <p>intended use or application have been fulfilled.</p> <p>RAM Validation ensures the system under consideration fulfils the related RAM requirements for the intended use or application prior to System Acceptance and Handover to Operations.</p> | |
| <p>Verification</p> | <p>Confirmation conducted at various lifecycle phases of development by examining the system to determine conformity to the requirements specified at the beginning of that lifecycle phase.</p> <p>Verification at each phase ensures conformity, through objective evidence of the deliverables from the life cycle phase to the requirements specified at the beginning of that life cycle phase.</p> | <p>BS EN 50126:2017</p> |

1. Overview

1.1 Purpose

- 1.1.1 The purpose of this document is to outline the process for RAM Verification and Validation (V&V). RAM V&V objective is to ensure that RAM requirements are met throughout the lifecycle of the system.
- 1.1.2 The intended audiences for this process are:
- a) Asset Class Teams
 - b) Project Delivery Teams
 - c) Design Teams
 - d) Sponsorship Office

1.2 Scope

- 1.2.1 Verification is conducted at each of the 12 phases of the system lifecycle to ensure conformity to the requirements specified at the beginning of each lifecycle phase. Conformity is ensured by gathering objective evidence of the deliverables from the current lifecycle phase and ensuring they meet the requirements specified from the beginning of that lifecycle phase.
- 1.2.2 The objective of verification is to demonstrate that the requirements of each lifecycle phase have been fulfilled.
- 1.2.3 RAM Validation ensures that the system fulfils its RAM requirements for use prior to system acceptance and handover to operations.
- 1.2.4 The objective of RAM validation lies in the system lifecycle: (Please refer to Appendix A- The Validation Process Application through the system lifecycle phases).
- 1.2.5 The system lifecycle approach provides a structure for planning, managing, controlling and monitoring all aspects of a system, including RAM, as the system under consideration progresses through the life cycle phases.
- 1.2.6 RAM Validation lies in phase 4 and 9 of the system lifecycle:
- a) RAM Validation in Phase 4**
 - 1) In phase 4 of the system lifecycle “Specification of RAM Requirements” the RAM Validation objective is to assure that RAM requirements have been properly specified.
 - 2) RAM Validation of the specification for RAM requirements ensures requirements cover all legal and technical aspects prior to moving forward to the design phase. Changes and modifications that occur in this phase are cost effective and of low consequence compared to changes that could occur during or after the design phase.
 - b) RAM Validation in Phase 9**

- 1) In phase 9 of the system lifecycle “System Validation” the RAM Validation objective is to ensure that the system meets the specified RAM requirements for its intended use.
- 2) Ensuring the system validation to RAM requirements is performed by implementing the RAM validation plan.
- 3) The RAM validation plan defines the stakeholders who are responsible for the validation process along the system lifecycle. This plan is dependent on contractual or legal frameworks.

1.2.7 The RAM Verification and Validation process applies to:

- a) All Metrolinx new assets (from the concept to the integration phase).
- b) All Metrolinx Non Like for Like Asset replacements.

1.2.8 This process does not apply to:

- a) Non-operational BUs (i.e. Finance, HR, etc.)
- b) Assets in the operations and maintenance phase.
- c) SOGR Like for Like replacements.

1.3 Key Responsibilities

Note: For detailed responsibilities, please refer to the Roles and Responsibilities Matrix (RACI), responsibilities will vary based on the contract type.

1.3.1 The following sets out the key responsibilities for each stakeholders, however in the event of conflict the RACI shall take precedence.

1.3.2 RAM Validation Responsibilities

1.3.2.1. The Project Delivery Team is responsible for the following tasks:

- a) Incorporating RAM requirements into the tender release.
- b) Incorporating the validation strategy, including acceptance criteria, demonstration and acceptance processes (and procedures) for potential contractors into the Tender Release.
- c) Planning and ensuring the completion of validation tasks for each phase of the system lifecycle.
- d) Validating with the Asset Class Teams and the RAMS team that the system meets the requirements for its intended use.

1.3.2.2. The **Asset Class Team** is responsible for the following tasks:

- a) Validating that the RAM requirements have been properly specified for its application prior to the design stage (stage 3) of the IP stages.
- b) Creating the RAM requirements validation report to ensure the specifications are properly detailed.
- c) Demonstrating that the specifications of the system meet the RAM requirements.
- d) Creating the RAM Validation plan for RAM requirements prior to design stage (stage 3) of the IP stages.

- e) Validating with the Project Delivery Team and the Asset Class Team that the system under consideration meets the specified requirements for its application.
- f) Updating the Validation plan throughout the lifecycle of the system.
- g) Perform RAM analysis during the design phase of the system lifecycle.

1.3.2.3. The RAMS team is responsible for the following tasks:

- a) Validating that RAM requirements have been properly specified for the intended use prior to the design stage (stage 3) of the IP stages.
- b) Creating the Validation plan for RAM requirements prior to the design stage (stage 3) of the IP stages.

1.3.3 RAM Verification Responsibilities

1.3.3.1. The **Project Delivery Team** is responsible for the following tasks:

- a) Ensuring the contractor confirms the system meets the RAM requirements, contractor confirmation of the system compliance must be demonstrated by providing RAM analysis as documented evidence.
- b) Managing the deviations between expected and actual results of the RAM analysis.

1.3.3.2. The Asset Class Team is responsible for the following tasks:

- a) Identifying the testing strategy and acceptance of the tests that are being proposed.
- b) Verifying that RAM analysis is accurate and adequate, in close coordination with RAMS team and the Project Delivery Team.
- c) Justifying the validation strategy chosen as a measure of the validation plan.
- d) Verifying the correctness, consistency and adequacy of test specifications and executed tests.

1.3.3.3. The RAMS team is responsible for the following tasks:

- a) Verifying the activities and the deliverables to ensure they comply with the requirements of the related lifecycle phase.
- b) Verifying that the RAM analysis is accurate and adequate, in close coordination with the Asset Class Team and the Project Delivery Team.
- c) Ensuring compliance of the current phase deliverables with the all the deliverables of all the former phases.

2. The RAM Verification and Validation Process

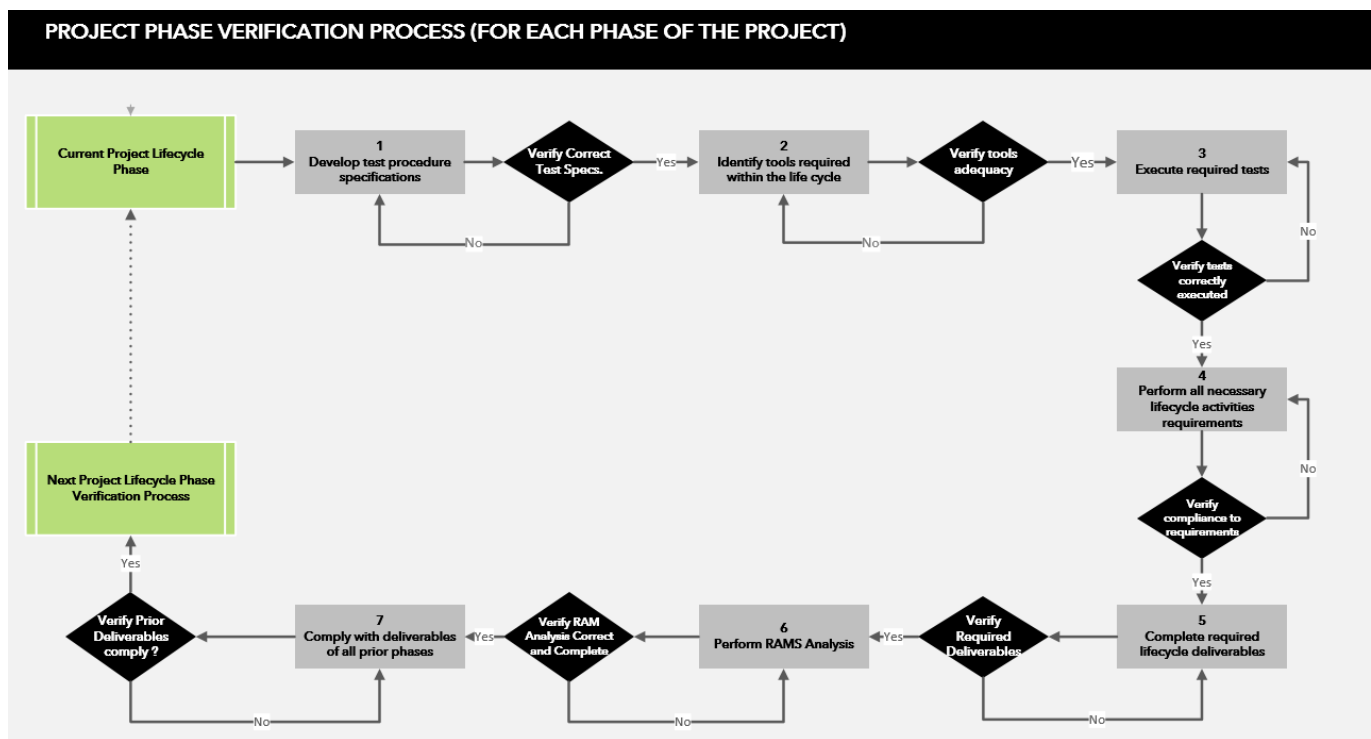
2.1 General

2.1.1 Within the system lifecycle, verification and validation processes occur separately. Verification occurs at each phase, and validation occurs in Phase 4 and Phase 9. The details of the processes are provided below.

2.2 The RAM Verification Process Flow Chart

2.2.1 Figure 2.1 illustrates the Verification Process.

FIGURE 2-1 VERIFICATION PROCESS FLOW CHART



2.3 The RAM Verification Process Narrative

2.3.1 The following steps describe the RAM Verification Process tasks in each lifecycle phase of the project as applicable:

- 1) The Asset Class Team must verify the correctness, consistency and adequacy of test specifications and executed tests.
- 2) The Project Delivery Team must verify that the methods, tools and techniques used within the lifecycle phase are adequate.
- 3) The RAMS Team must ensure the activities and the deliverables are verified and comply with the requirements of the related lifecycle phase.
- 4) The RAMS Team must verify the correctness and adequacy of the RAM analysis.

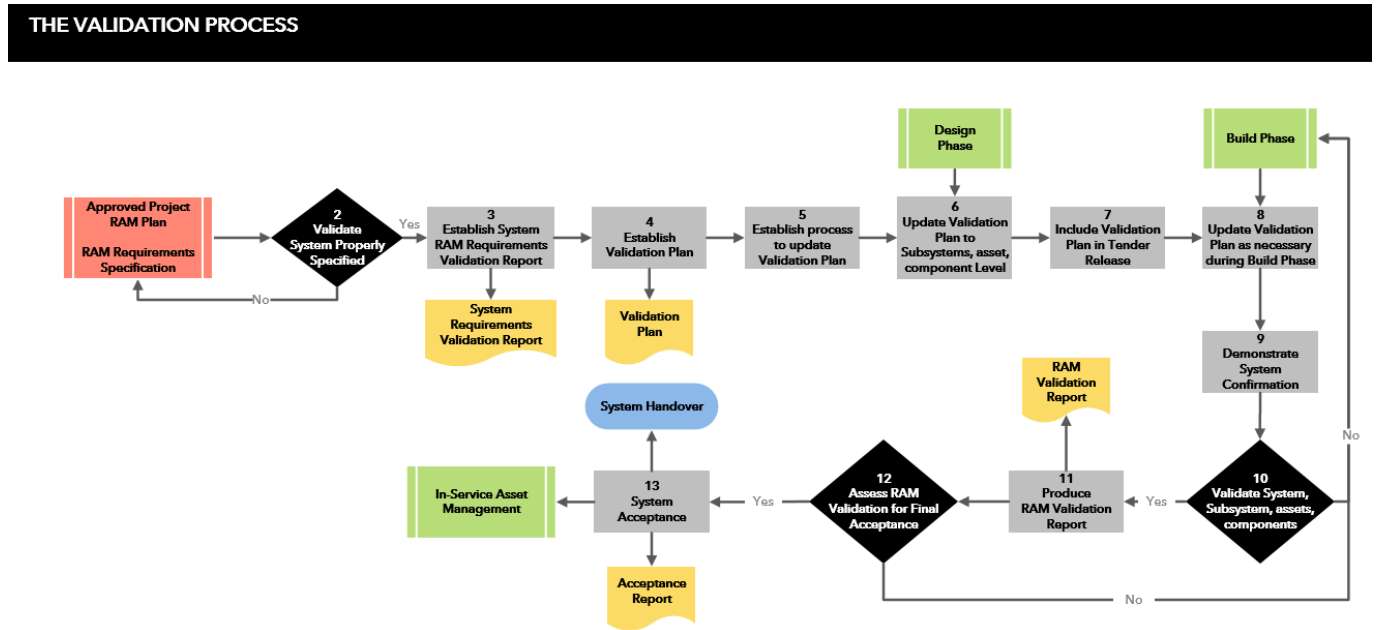
Note: In the design phase of the system lifecycle, the contractor confirms the system meets the RAM requirements, contractor confirmation of the system compliance must be demonstrated by providing RAM analysis as documented evidence.

- a) The RAM Analysis must consist of the following:
 - i. RAM Requirements:
 - A. Reliability Requirements for the system and subsystems
 - B. Availability Requirements for the system and subsystems
 - C. Maintainability Requirements for the system and subsystems
 - ii. Prediction Methodology for the Reliability, Availability and Maintainability of the design including:
 - A. Reliability Availability, and Maintainability predicted values and measuring definitions,
 - B. Feasibility evaluation
 - C. Comparison of alternative configurations
 - D. Identification of potential problems
 - E. Determination of data deficiencies and trade-off decisions
 - F. Reliability Availability and Maintainability Prediction Calculations
 - iii. Block diagrams and mathematical models.
 - iv. Data for Reliability, Availability and Maintainability Prediction:
 - A. Historical/Vendor/Manufacturer Data
 - B. Estimates based on similar assets
 - v. Compliance to Maintainability and Availability Requirements:
 - A. System calculations for reliability availability and maintainability indicating the ability of the design to perform in accordance with the specified RAM requirements
- 5) The RAMS Team must ensure compliance of the deliverables in each phase with the deliverables of the former phases.

2.4 The RAM Validation Process Flow Chart

2.4.1 illustrates the Validation Process.

FIGURE 2-2 VALIDATION PROCESS FLOW CHART



2.5 The RAM Validation Process Narrative

2.5.1 The following steps describe the RAM Validation Process throughout the system lifecycle IP stages:

Note: The Investment Panel (“IP”) is Metrolinx’s accountable governance body for benefits management of business cases across the entire system lifecycle, as defined by the IP Gates - Please refer to Appendix B - The Mapping of lifecycle phases to IP Stages)

- 1) The RAMS team, in close coordination with the Asset Class Team, must validate that the specifications for the RAM system are properly specified for its intended application. This is completed in the system requirements phase (phase 4) of the system lifecycle. (This is included in the develop stage (stage 2) of the IP stages).
- 2) The Asset Class Team is to establish the RAM validation report during the system requirements phase (phase 4) of the system lifecycle.
- 3) This system level RAM validation report should include the following:
 - a) System identification:
 - i. The system under consideration
 - ii. The documents (including other items) used for the validation
 - iii. Processes, technical support tools and equipment used (if applicable)
 - iv. The simulation models used (if applicable)

- b) Confirmation that process activities have followed what was planned. (Note that any deviations from the RAM plan will be documented with justification.)
 - c) Validation of the system safety requirements against the risk assessment processes that were conducted up to the end of the risk analysis phase (phase 3) of the system lifecycle.
 - d) Validation of the RAM requirements in comparison to the specified RAMS targets and higher-level RAMS policies.
 - e) Confirmation that RAM Requirements are adequately analysed and specified to ensure the system works as intended.
- 4) In close coordination with the RAMS team, the Asset Class Team must then create the Validation Plan in order to achieve the specified RAM requirements during the system requirements phase (phase 4) of the system lifecycle.
 - 5) This Validation plan should outline the following:
 - a) The specific validation tasks and deliverables for each phase of the system lifecycle. (Please refer to Appendix-D for further details)
 - b) Justification of the validation strategy chosen. The justification should be prepared in conjunction with the Business unit and must include the following:
 - i. Testing strategy;
 - ii. Acceptance of the test strategies by the one(s) conducting the testing;
 - iii. Witness (including extent) of the test strategy.
 - c) The steps necessary to demonstrate the adequacy of the specification of the system in fulfilling the requirements.
 - d) For each subsystem and piece of equipment the following should be defined:
 - i. The techniques and measures to be used.
 - ii. The test and analysis to be used and the reporting required.
 - iii. Management of the deviations between expected and actual results of the analysis.
 - iv. Management of non-compliances and safety constraints arising from any deviations.
 - v. Management of conditions and constraints that arise from the deviations, and how they will be considered in the next lifecycle tasks.
 - e) The steps necessary for the analysis are both adequate and complete in order to fulfil the RAM requirements.
 - 6) The Asset Class Team must then create a system to ensure the RAM validation plan for RAM requirements are updated throughout the lifecycle of the system. This should be applied in the system requirements phase (phase 4) of the system lifecycle.
 - 7) The Project Delivery Team must then communicate the RAM requirements and the validation strategy to the potential contractors prior to the Tender Release. This includes the acceptance criteria used and the demonstration of acceptance processes and procedures.

- 8) The Project Delivery Team must then ensure that contractors document (with evidence) that system confirmation meets the RAM requirements. This should be completed in the system validation phase (phase 4) of the system lifecycle.
- 9) The Project Delivery Team must then validate with the Asset Class Team that the system under consideration meets the specified requirements for the intended use during the system validation phase (phase 4) of the system lifecycle. This acceptance is done prior to the handover to the Asset Class Team.
- 10) The Asset Class Team must then create the RAM validation report as a main deliverable of the system validation phase (phase 9) of the system lifecycle.
- 11) The Validation report should include the following:
 - a) Identification and name of:
 - i. The system under consideration
 - ii. The documents or other items used for the validation
 - iii. Processes, technical support tools and equipment used, (including calibration data)
 - iv. Simulation models used (if applicable)
 - b) Confirmation that the process and activities defined in the validation plan have been met. Deviations from the validation plan are to be documented with justification.
 - c) Confirmation that any implemented corrective actions in the development and verification stage follow the change management process. Clearly identify any deviations that may need to be followed.
 - d) Evaluate the requirements for the analyses to cover the full system under consideration.
 - e) Identify the tests executed by the validator (if any).
 - f) Evaluate the correctness, consistency and adequacy of the qualification according to the technology related standards;
 - g) Conclusion of the validation results; and,
 - h) Determination whether the system under consideration fulfils the requirements for its intended use in the environment.

Note: With the validation plan prepared, update as necessary during Phases 5 to 8,

- 12) The Project Delivery Team must then handover the asset and accepted system to the Asset Class Team by the end of the system acceptance phase (phase 10) of the system lifecycle and the build stage (stage 4) of the IP stages.
- 13) The Asset Class Team must then assess the RAM validation tasks according to the defined risk acceptance criteria and create the asset acceptance report as the final deliverable of the system acceptance phase (phase 10). The acceptance report should include a confirmation that the delivered product (including the system or process) is fit for service.

END: The process ends here.

Appendix A - The application of the processes through the System Lifecycle Phases

A.1 The Verification Process Application through the system lifecycle phases

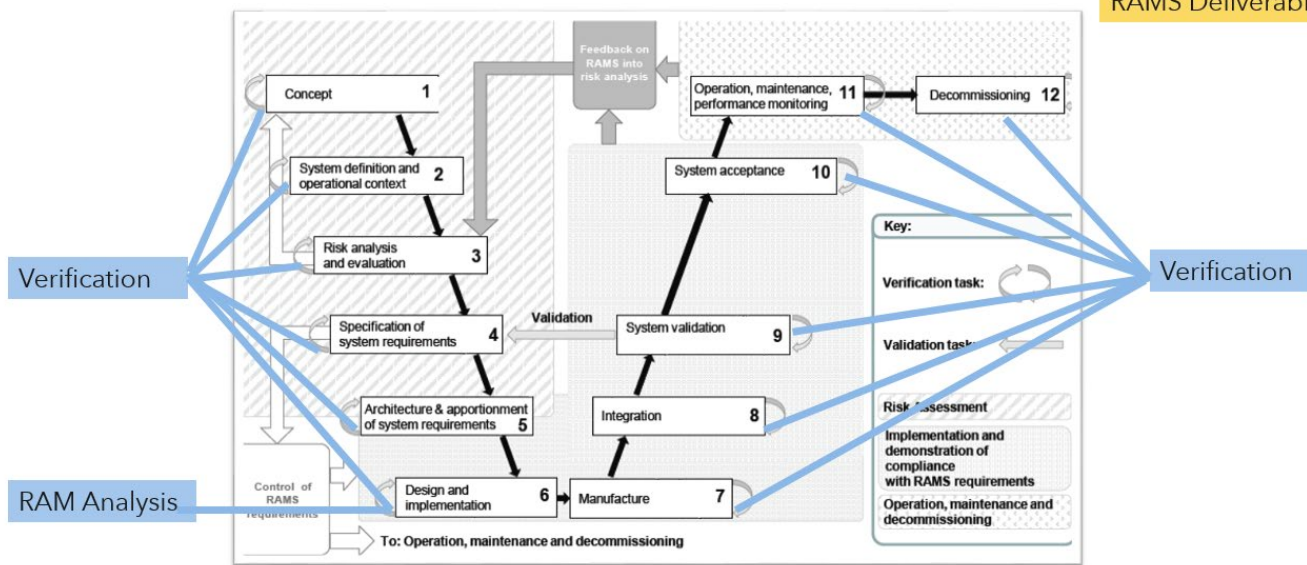
A.1.1 The Verification Process Application through system lifecycle phases.

A.1.2 The figure below illustrates the occurrence of the verification through the system lifecycle.

FIGURE A- 1 THE VERIFICATION PROCESS APPLICATION THROUGH SYSTEM LIFECYCLE PHASES

APPLICABILITY THROUGH LIFECYCLE PHASES - VERIFICATION

RAMS Tasks
RAMS Deliverables



A.2 The Application of the Validation Process through the system lifecycle phases

A.2.1 The Validation Process Application through system lifecycle phases.

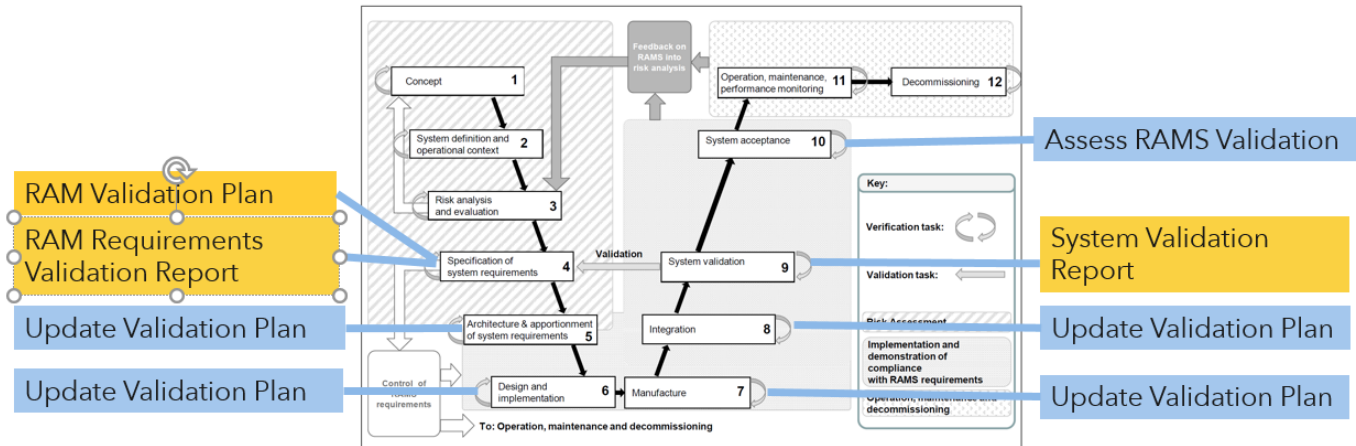
A.2.2 The system lifecycle approach provides a structure for planning, managing, controlling and monitoring all aspects of a system, including RAM, as the system under consideration progresses through the life cycle phases.

A.2.3 The figure below illustrates the main RAM Validation tasks and activities throughout the system lifecycle.

FIGURE A- 2 THE VALIDATION PROCESS APPLICATION THROUGH SYSTEM LIFECYCLE PHASES

APPLICABILITY THROUGH LIFECYCLE PHASES - VALIDATION

RAMS Tasks
 RAMS Deliverables



Appendix B - Mapping of the Lifecycle phases to the IP Stages

B.1 Mapping of the lifecycle phases to the IP stages

- B.1.1 The Mapping of the lifecycle phases to the IP stages.
- B.1.2 The System lifecycle phases are linked to IP stages to ensure alignment and facilitate assigning accountability as a project moves through the system lifecycle.
- B.1.3 For more details on the IP stages and gate descriptions, please refer to Investment Panel ToR (03-1-2019).

FIGURE B- 1 THE MAPPING OF THE LIFECYCLE PHASES (PHASES 1-12) TO THE IP STAGES (STAGES 0-4)

MAPPING OF LIFECYCLE PHASES TO IP STAGES

