T MU AM 06006 ST

Standard

Systems Engineering

Version 2.0

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Standard governance

Owner: Manager Systems Engineering Process, Asset Standards Authority

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Approver: Executive Director, Asset Standards Authority on behalf of the ASA Configuration Control Board

Document history

Version	Summary of changes
1.0	First issue 3 September 2015
2.0	Updates based on comments from first review

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Preface

The Asset Standards Authority (ASA) is a key strategic branch of Transport for NSW (TfNSW). As the network design and standards authority for NSW Transport Assets, as specified in the *ASA Charter*, the ASA identifies, selects, develops, publishes, maintains and controls a suite of requirements documents on behalf of TfNSW, the asset owner.

The ASA deploys TfNSW requirements for asset and safety assurance by creating and managing TfNSW's governance models, documents and processes. To achieve this, the ASA focuses on four primary tasks:

- publishing and managing TfNSW's process and requirements documents including TfNSW plans, standards, manuals and guides
- deploying TfNSW's Authorised Engineering Organisation (AEO) framework
- continuously improving TfNSW's Asset Management Framework
- collaborating with the Transport cluster and industry through open engagement

The AEO framework authorises engineering organisations to supply and provide asset related products and services to TfNSW. It works to assure the safety, quality and fitness for purpose of those products and services over the asset's whole-of-life. AEOs are expected to demonstrate how they have applied the requirements of ASA documents, including TfNSW plans, standards and guides, when delivering assets and related services for TfNSW.

Compliance with ASA requirements by itself is not sufficient to ensure satisfactory outcomes for NSW Transport Assets. The ASA expects that professional judgement be used by competent personnel when using ASA requirements to produce those outcomes.

About this document

This standard establishes mandatory requirements for systems engineering (SE) management for the planning, acquisition and delivery of assets owned by TfNSW across the asset life cycle.

This standard defines responsibilities for TfNSW and its engineering supply chain in carrying out SE on multimodal, multidisciplinary engineering projects.

This standard and SE practice in general, is placed in a broader context of asset management, and therefore SE is a methodology that supports the TfNSW asset management framework.

Updates of this document include the following:

- inclusion of 'Demand/need' stage in TfNSW asset life cycle
- removal of references to specific TfNSW divisions
- change from heavy rail focus to multi-modal

This is a second issue.

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1. Introduction

A system is a combination of hardware, software, people, processes and support arrangements that meets customer needs as a product or service. A system can include data, facilities, materials and naturally occurring features such as terrain and waterways.

Within Transport for NSW (TfNSW) systems engineering (SE) is an interdisciplinary approach to ensure successful complex transport systems.

The introduction of a new or altered system into the transport network requires the analysis, synthesis, verification and validation (V&V) of the system over the whole of its life cycle.

A system includes the functions and performance expectations of the system and its support requirements. To manage this effectively and efficiently, ensuring that customer needs and strategic intents are fulfilled at all times, requires organisations to establish frameworks for SE, including configuration management (CM).

The SE approach is fundamental to ensuring high performing, fit-for-purpose and cost-effective systems. Using a multidisciplinary approach, SE determines the following outputs at the early stages of the system life cycle:

- functional, performance, non-functional and interface requirements and constraints
- appropriate management process requirements
- production or construction requirements and constraints
- sustainable operational and maintenance support requirements
- system disposal requirements

SE transforms a need into a definitive system configuration and ensures the system's compatibility and interfaces with related physical and functional requirements. Needs are seen as defining the problem domain while a definitive system configuration is viewed as the solution domain.

SE can be applied equally in the problem domain through the normal SE processes as well as the solution domain.

The SE approach considers the system and asset life cycle outcomes measured by, reliability, availability, maintainability and safety (RAMS), performance and cost-effectiveness.

2. Purpose

This standard provides a structured set of requirements to establish an SE framework and to manage SE activities within transport projects ranging from simple to complex across the system and asset life cycle.

2.1. Scope

This standard covers requirements for planning and execution of SE activities associated with planning, acquisition, development, utilisation and disposal of new or altered transport systems.

This standard is informed by and expands on a portion of the technical and management processes and requirements identified in AS/NZS ISO/IEC/IEEE 15288 *Systems and software engineering – System life cycle processes.* This standard also expands on the AEO (Authorised Engineering Organisation) authorisation requirements in T MU MD 00009 ST *AEO Authorisation Requirements*.

2.2. Application

This standard applies at a number of levels including multimodal transport network, transport mode, line and route and to all TfNSW programs and projects.

This standard applies to all entities within the NSW transport cluster. It also applies to AEOs in the supply chain involved in the planning, acquiring, operating, maintaining and disposing of new or altered systems. It is expected that AEOs understand and apply the relevant systems engineering management activities in this standard.

Application of this standard supports compliance with the following key documents and legislation:

- CP14005 *Transport Asset Management Policy*
- T MU AM 01001 ST *Life Cycle Costing*
- 50-ST-162/3.0 *Asset Life Cycle Safety Management Standard*
- *Rail Safety National Law (NSW) 2012*
- *Work Health and Safety Act (NSW) 2011*

This standard should be read in conjunction with the SE suite of documents as shown in Appendix A.

The concepts and principles described in this standard should be scaled and tailored to suit the level of novelty, complexity, scale and risk associated with each project within the capacity and maturity of the organisation.

> *Note: The application of all elements of this standard should be carefully considered to ensure the appropriate level of rigour, and to ensure that value for money and safety are achieved for the full system life cycle including capital expenditure (CapEx) and operational expenditure (OpEx). It should also be noted that CapEx and OpEx should not be planned separately.*

3. Reference documents

The following documents are cited in the text. For dated references, only the cited edition applies. For undated references, the latest edition of the referenced document applies.

Australian standards

AS IEC 61000.6.5 Electromagnetic compatibility (EMC) Part 6.5: Generic standards – Immunity for equipment used in power station and substation environment

AS ISO 55001 Asset management – Management systems – Requirements

AS/NZS ISO/IEC/IEEE 15288 Systems and software engineering – System life cycle processes

AS/RISSB 7722 EMC Management

Transport for NSW standards

T HR HF 00001 ST Human Factors Integration – Rolling Stock

T MU AM 01001 ST Life Cycle Costing

T MU AM 02001 ST Asset Information and Register Requirements

T MU AM 04001 PL TfNSW Configuration Management Plan

T MU AM 06001 GU AEO Guide to Systems Architectural Design

T MU AM 06002 GU AEO Guide to Reliability, Availability and Maintainability

T MU AM 06006 GU Systems Engineering

T MU AM 06007 GU Guide to Requirements Definition and Analysis

T MU AM 06008 GU Operational Concept Definition

T MU AM 06010 GU Business Requirements Specification

T MU AM 06004 ST Requirements Schema

T MU AM 06008 ST Operational Concept Definition

T MU AM 06009 ST Maintenance Concept Definition

T MU AM 06011 TI Transport Network Architecture

T MU HF 00001 GU AEO Guide to Human Factors Integration

T MU HF 00001 ST Human Factors Integration – General Requirements

T MU MD 00009 ST AEO Authorisation Requirements

T MU MD 20001 ST System Safety Standard for New or Altered Assets

TS 10504: 2013 AEO Guide to Engineering Management

TS 10506: 2013 AEO Guide to Verification and Validation

TS 10507: 2013 AEO Guide to Systems Integration

TS 10753: 2014 Assurance and Governance Plan Requirements

50-ST-162/3.0 Asset Life Cycle Safety Management Standard (available on request from standards@asa.transport.nsw.gov.au)

Legislation

Rail Safety National Law (NSW) 2012

Work Health and Safety Act (NSW) 2011

Other reference documents

TfNSW 2015, Asset Management Framework Overview (available on request from standards@transport.nsw.gov.au)

CP14005 Transport Asset Management Policy (available on request from standards@asa.transport.nsw.gov.au)

International Council on Systems Engineering 2015, INCOSE Systems Engineering Handbook: A guide for system life cycle processes and activities, version 4.0, Wiley

4. Terms and definitions

The following terms and definitions apply in this document:

AEO Authorised Engineering Organisation

ASA Asset Standards Authority

BRS business requirements specification

CM configuration management

concept of operations verbal and graphic statement, in broad outline, of an organisation's assumptions or intent in regard to an operation or series of operations (ANSI/AIAA G-043-1992)

Note 1 The concept of operations frequently is embodied in long-range strategic plans and annual operational plans. In the latter case, the concept of operations in the plan covers a series of connected operations to be carried out simultaneously or in succession. The concept is designed to give an overall picture of the organisation operations. See also operational concept.

Note 2 It provides the basis for bounding the operating space, system capabilities, interfaces and operating environment. (ISO/IEC/IEEE 29148)

ConOps concept of operations

EMC electromagnetic compatibility

FRACAS failure reporting, analysis and corrective action system

HFI human factors integration

ICD interface control document

INCOSE International Council on Systems Engineering

IRS interface requirements specification

JOS judgment of significance; an assessment of the technical risk introduced by the implementation of the design considers both the probability and consequence of partial performance or failure of a design

MCD maintenance concept definition

OCD operational concept definition

operational concept verbal and graphic statement of an organisation's assumptions or intent in regard to an operation or series of operations of a system or a related set of systems (ANSI/AIAA G-043-1992)

Note The operational concept is designed to give an overall picture of the operations using one or more specific systems, or set of related systems, in the organisation's operational environment from the users' and operators' perspective. See also concept of operations. (ISO/IEC/IEEE 29148)

P50 cost estimate estimate based on a 50% probability that the cost will not be exceeded

P90 cost estimate estimate based on a 90% probability that the cost will not be exceeded

RAM reliability, availability and maintainability

RAMS reliability, availability, maintainability and safety

RIM rail infrastructure manager

RSO rolling stock operator

SBS system breakdown structure

SE systems engineering

SEMP systems engineering management plan

SRS system requirements specification

SSRS sub-system requirements specification

TfNSW Transport for NSW

V&V verification and validation

validation 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 objective evidence needed for a validation is the result of a test or other form of determination such as performing alternative calculations or reviewing documents.

Note 2 to entry: The word "validated" is used to designate the corresponding status.

Note 3 to entry: The use conditions for validation can be real or simulated.
(AS/NZS ISO 9000)

verification confirmation, through the provision of objective evidence, that specified requirements have been fulfilled

Note 1 to entry: The objective evidence needed for a verification can be the result of an inspection or of other forms of determination such as performing alternative calculations or reviewing documents.

Note 2 to entry: The activities carried out for verification are sometimes called a qualification process.

Note 3 to entry: The word verified is used to designate the corresponding status.
(AS/NZS ISO 9000

5. TfNSW asset or system life cycle

SE is one of a collection of methodologies that support TfNSW total asset management over the asset life cycle as documented in the Asset Management Framework Overview published by TfNSW. The TfNSW asset or system life cycle adopts the AS ISO 55001 *Asset management – Management systems – Requirements* approach and comprises five main stages as follows:

- demand and need
- plan
- acquire
- operate and maintain
- dispose

AS/NZS ISO/IEC/IEEE 15288 and the *INCOSE Systems Engineering Handbook* published by the International Council on Systems Engineering (INCOSE) define the system life cycle stages as follows:

- concept
- development

- production
- utilisation and support
- retirement

Section 5.2 to Section 5.6 outline how the INCOSE system life cycle stages are interpreted and mapped to the TfNSW asset or system life cycle stages.

The Asset Standards Authority (ASA) has adopted AS/NZS ISO/IEC/IEEE 15288 and the supporting INCOSE system life cycle model and approach and is aiming to standardise the SE approach by applying a tailored INCOSE approach to the TfNSW model. This life cycle model is also consistent with the life cycle activities and responsibilities defined in the 50-ST-162/3.0. Figure 1 shows the relationship between the asset life cycle stages and CM gateways.

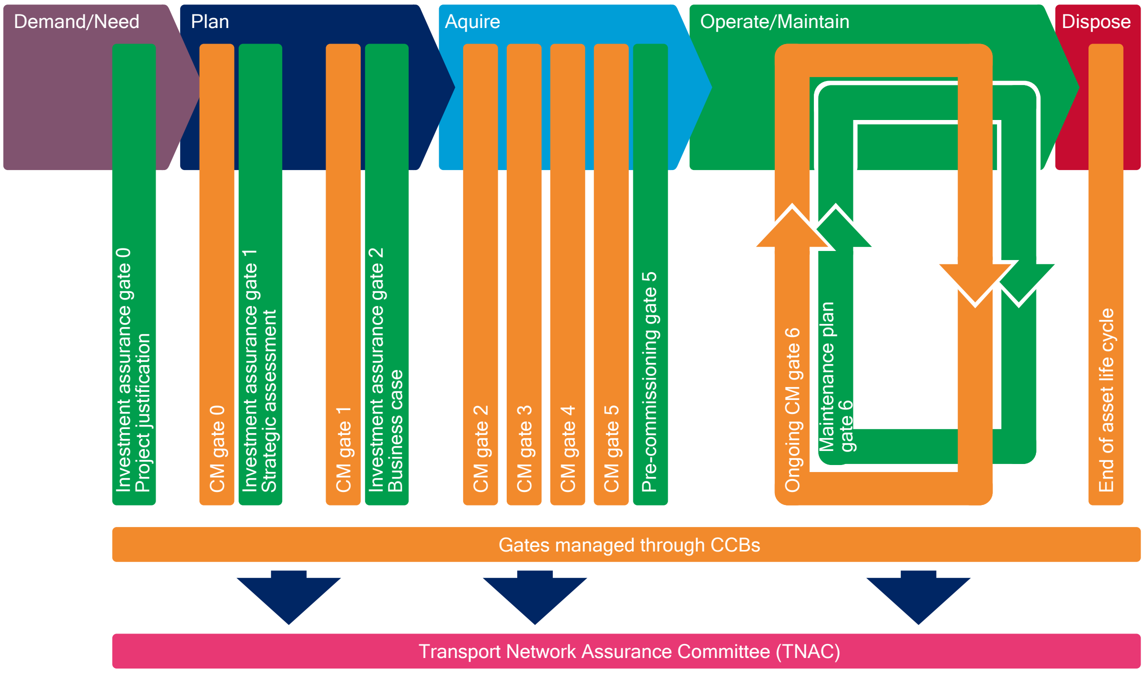

Figure 1 - TfNSW asset life cycle model

5.1. System V model

TfNSW's system life cycle and engineering management definitions are based on the SE V model described in the *INCOSE Systems Engineering Handbook* and the requirements provided in AS/NZS ISO/IEC/IEEE 15288.

The TfNSW life cycle stages, CM gates and investment gateways are aligned with the V model as described in the *INCOSE Systems Engineering Handbook*.

Figure 2 illustrates the TfNSW system life cycle model, showing the relationship between the CM gates and the stages of the asset life cycle.

The system V life cycle model maps system definition against all life cycle stages. System definition increases in granularity from the system, through subsystem, to unit level.

A summary of the key activities, deliverables and responsible parties at each life cycle stage is shown in Appendix B.

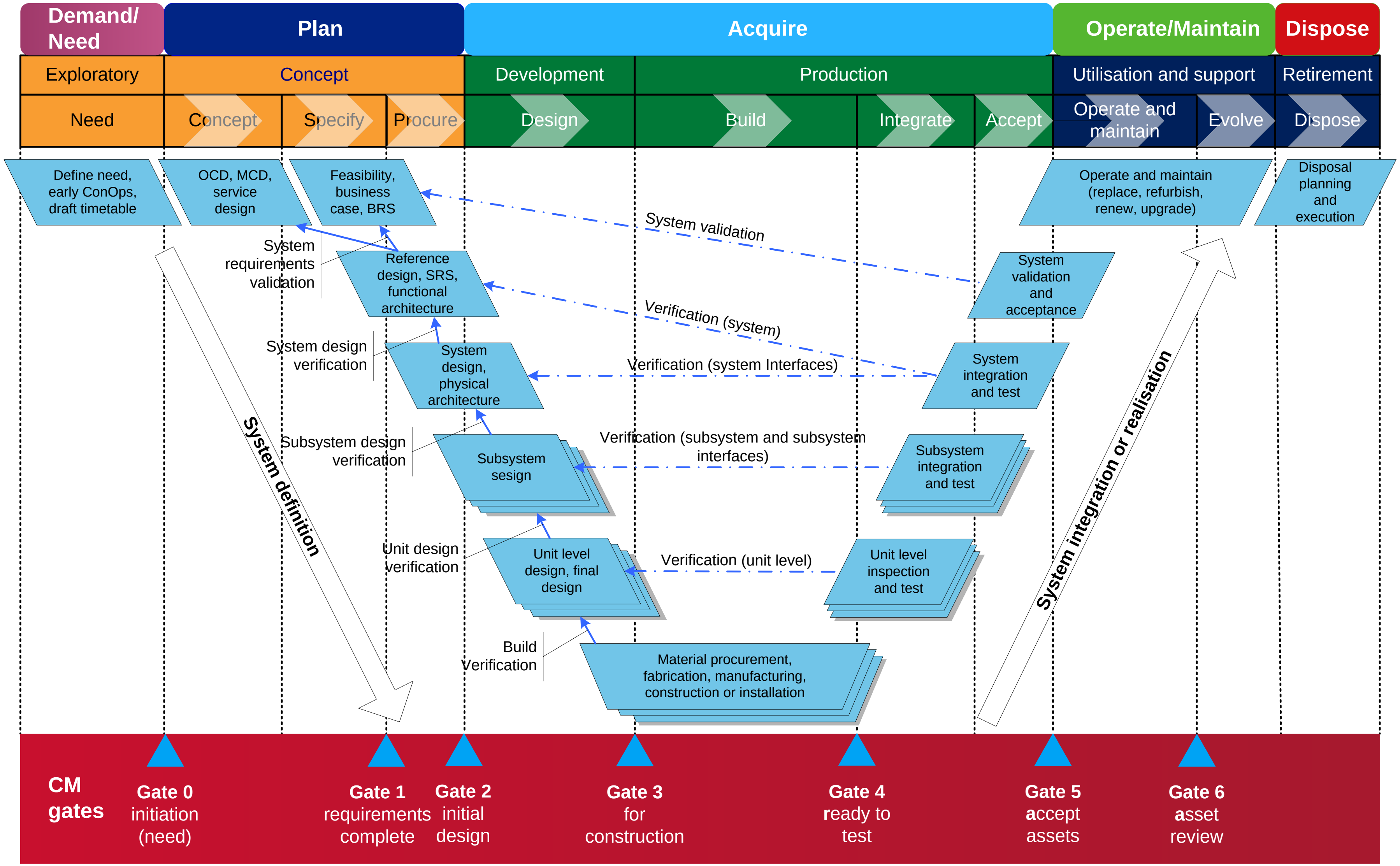

Figure 2 - TfNSW system V life cycle model with configuration gates

5.1.1. Parties involved

There are different parties involved at different stages throughout the system life cycle. The customer organisation, referred to as the sponsor of the project, sets the direction for the organisation through a concept of operations (ConOps). The ConOps provides input to an operational concept definition (OCD), maintenance concept definition (MCD) and systems engineering management plan (SEMP) developed at the outset of the project in both the demand and need and plan stages of the life cycle.

The system or asset is procured under the auspices of the project which shall be managed by the entity responsible for project delivery within TfNSW. Project managers are supported by a number of related disciplines such as the following:

- safety and engineering assurance
- SE
- human factors
- reliability, availability and maintainability (RAM)
- other specialist areas

SE in particular is an important discipline which is responsible to the project delivery authority to perform the technical management of the project throughout all stages of the life cycle. For projects requiring the development of SE related artefacts mentioned in this standard, the project team shall consult with an SE subject matter expert within the customer organisation. The project team should also include the operator and maintainer during the development of the OCD and MCD to better define the support role in sustaining, operating and maintaining the system throughout its life.

In addition to the SE subject matter experts, there are many others within the customer organisation with a stake in the successful implementation of the project. These stakeholders generally include representatives from the strategic planning, finance, CM, program management and asset management areas of the organisation. The project team should engage with all these areas to ensure that the project is consistent with the latest frameworks, processes and standards.

5.2. Demand and need stage

In the demand and need stage TfNSW responds to the needs and expectations of stakeholders, associated with the work program or project, in a manner that best matches service delivery to the supporting assets and the available resources.

TfNSW as the customer in TfNSW funded projects should workshop and develop a ConOps high level business needs and needs analysis.

Artefacts produced in this stage shall be submitted for CM gate 0 and investment gate 0.

5.3. Plan stage

The plan stage involves translating the defined need into a system acquisition plan and specification and consists of the following phases:

- concept
- specify
- procure

TfNSW holds ownership of all artefacts produced at this stage of the life cycle and shall be the only party to have authority to sign-off on these artefacts.

The plan stage should begin with an idea for a system being introduced as a result of business planning. Early consideration of the possible options results in the confirmation of the early business needs for the system or asset and shall be elaborated by a business case. A strategic business requirements specification (BRS) may also be developed to translate the early business needs into a draft set of business requirements to support the business case.

A business case shall justify the capital expenditure and operational expenditure of organisational resources on acquisition of the system or asset. The plan stage should determine if the project is feasible or cost-effective to proceed to the acquire stage. For this reason, the plan stage should include research to ensure that feasible and cost-effective projects proceed to the acquire stage of the asset life cycle. The plan stage consists of the concept, specify and procure phases.

5.3.1. Concept

The concept phase corresponds to the concept stage in AS/NZS ISO/IEC/IEEE 15288 and *INCOSE Systems Engineering Handbook*. Key responsible parties in the concept phase include the following:

- customer organisation (TfNSW) which in this phase shall be the entity responsible for strategic planning or project delivery
- AEOs contracted to provide technical advice in this phase as technical advisors
- transport agencies, operators and maintainers providing services as an AEO under contract to TfNSW may in some cases hold this responsibility, and if not, they should be consulted as key stakeholders in this phase

This phase focuses on the business needs and requirements as opposed to the system or product level requirements. The entity responsible for strategic planning should evaluate, analyse and select a preferred candidate concept by providing substantial justification in the draft business case.

Safety responsibilities of all parties in this phase shall be in accordance with the TfNSW safety management system (SMS) and T MU MD 20001 ST *System Safety Standard for New or Altered Assets*.

Key activities and deliverables should include the following:

- transport performance modelling
- transport service design
- preliminary OCD and MCD
- baseline timetable
- concept design
- draft benefits realisation management plan
- draft business case
- draft SEMP
- draft V&V plan
- P50 cost estimate
- BRS

All key parties responsible for delivering the concept phase of the plan stage shall determine the effort of SE required by considering the complexity, amount of planning required and tools and resources required. Scaling and tailoring on the project should be completed before the tendering process begins (that is, acquire stage) but can also be delayed until the end of concept design as requirements mature.

Artefacts produced in this phase shall be submitted to CM gate 1.

5.3.2. Specify

The specify phase corresponds to the concept stage in AS/NZS ISO/IEC/IEEE 15288 and *INCOSE Systems Engineering Handbook*. Key responsible parties include the following:

- customer organisation (TfNSW) which in this phase shall be the entity responsible for strategic planning or project delivery

- transport agencies or operators and maintainers providing services under contract to TfNSW
- AEOs contracted to provide technical advice in this phase as technical advisors

There are situations where the organisation responsible for specification and procurement may not be the party responsible for planning or project delivery, and therefore this applies to any delivery entity working in these phases.

Key activities and deliverables should include the following:

- detailed transport modelling
- updated OCD and MCD
- proposed viable options
- updated timetable
- updated BRS
- updated SEMP
- updated V&V plan
- draft P90 cost estimate
- draft business case

During these phases, high-level system assurance requirements are established, including conducting a preliminary hazard analysis (PHA) of the reference design to establish a system hazard log, early consideration of human factors integration (HFI) and setting of RAM and other key system performance targets.

Artefacts produced in this phase shall be submitted to CM gate 1.

5.3.3. Procure

The procure phase corresponds to the concept stage in AS/NZS ISO/IEC/IEEE 15288 and *INCOSE Systems Engineering Handbook*. Key responsible parties include the following:

- customer organisation (TfNSW) which in this phase shall be the entity responsible for strategic planning or project delivery
- transport agencies or operators and maintainers providing services under contract to TfNSW
- AEOs contracted to provide technical advice in this phase as technical advisors

In addition to the specify phase, the procure phase focuses on the initial reference design. At this phase of the life cycle, any procurement activities for long lead items shall be identified based on the needs of the preferred candidate concept in the draft business case.

Key activities and deliverables should include the following:

- final approved OCD and MCD
- approved timetable
- final BRS
- preferred option selection
- draft systems requirements specification (SRS)
- reference design
- P90 cost estimate
- updated SEMP
- updated V&V plan
- tender documentation
- final approved business case

Artefacts produced in this phase shall be submitted to CM gate 2.

5.4. Acquire stage

The acquire stage corresponds to the development and production stage in AS/NZS ISO/IEC/IEEE 15288 and *INCOSE Systems Engineering Handbook*.

Key responsible parties include the following:

- customer organisation (TfNSW) which in this phase shall be the entity responsible for project delivery
- any other asset delivery organisation that is established by TfNSW, including acquisition projects managed by transport agencies or operators and maintainers
- AEOs contracted to provide design, supply, manufacturing or fabrication, site installation, integration, testing and commissioning services to TfNSW in this life cycle phase

While most major capital works are carried out under the project delivery entity within TfNSW, there may be exceptions where a rail infrastructure manager (RIM) or rolling stock operator (RSO) performs capital works that require a SE life cycle approach. While a significant proportion of capital works undertaken by a RIM or RSO are projects that involve refurbishment, like-for-like replacement or minor performance enhancements, there remains an element of major capital works.

Key phases in this stage of the system life cycle include the following:

- Design - including preliminary and detailed design up to approved for construction status.
- Build - including manufacturing, fabrication and procurement of original equipment manufacturer (OEM), commercial off-the-shelf or developmental systems. This phase should also include the development of data sets such as communication based interlocking data set for wireless communication systems.
- Integrate - including factory and site integration of systems and testing and commissioning.
- Accept - including operational readiness and validation.

Key activities and deliverables include the following:

- development of detailed designs
- bills of materials and product specifications
- process specifications
- material specifications
- procuring systems
- V&V strategies
- RAM performance considered
- fabricating products
- site installation and integration
- system testing
- review benefits realisation plan
- commissioning and operational readiness demonstration for hand back to the asset owner or handover to the contracted operator and maintainer of that asset

Additional deliverables include integration and interface documentation as well as test plans that support system integration and testing, as discussed in Section 7.4.

The design phase in the acquire stage shall include a design safety assurance report and consider the retirement of the system whether it will be reused, remanufactured, recycled or disposed.

The Transport Network Assurance Committee (TNAC) or delegated configuration control board (CCB) within the transport cluster should inform the acceptance authority and the accredited RIM or RSO with responsibility for operating or maintaining the asset throughout the life cycle.

5.5. Operate and maintain stage

The operate and maintain stage corresponds to the utilisation stage in AS/NZS ISO/IEC/IEEE 15288 and *INCOSE Systems Engineering Handbook*. Key responsible parties include the following:

- transport operators and maintainers providing services under contract to TfNSW
- AEOs sub contracted to provide asset maintenance services in this life cycle phase

Key activities and deliverables include the following:

- asset acceptance from the asset acquisition and delivery organisation at the end of the acquire stage
- scheduled asset condition assessments
- preparing asset maintenance plans
- performing failure reporting, analysis and corrective action system (FRACAS)
- carrying out asset maintenance and logistic support activities against these plans
- modifications to meet current operational and support requirements
- identifying failures during operational use

From a safety assurance point of view, an operational safety argument should be developed to demonstrate the safety of the delivered asset in accordance with T MU MD 20001 ST.

Another key activity should be to review the benefits realisation plan developed in the plan stage of the life cycle. The purpose of this review is to provide assurance through peer review as to whether the benefits outlined in the approved business case have been or are likely to be delivered and whether the project is providing ongoing value for money for the community. The benefits realisation review should seek to do the following:

- establish the baseline for benefits against which all outcomes in this and subsequent reviews will be assessed
- develop profiles for each specific benefit so that they can be consistently measured across time
- establish the benefits monitoring and reporting process for the project
- evaluate outcomes and provide feedback to benefit owners in relation to the measurement of delivered benefits and the key factors influencing benefit outcomes

5.6. Dispose stage

The dispose stage corresponds to the retirement stage in AS/NZS ISO/IEC/IEEE 15288 and *INCOSE Systems Engineering Handbook*.

Key stakeholders involved include the following:

- customer organisation (TfNSW)
- transport operators and maintainers
- other asset operation and maintenance organisations, which could be AEOs, who make performance-based decisions on when an asset is to be retired from service
- other stakeholders such as secure IT asset disposal, data centre service providers and environmental agencies

Disposal of life expired assets generally occurs during introduction of new assets on brown field sites as a result of major refurbishment, end of life capital renewals, changes in asset utilisation or performance capability upgrades. This stage of the life cycle has important implications for safety and environment management and for ongoing support costs. The retirement of an asset shall be considered during acquisition and the implications of selected materials and design solutions on life cycle cost clearly identified.

To determine whether the existing system is suitable for current and future network operations, the project delivery team shall undertake the following three broad tasks:

- identify reasons for potential retirement
- identify potential retirement methods for the system
- identify design issues that may arise as a result of disposal

Key activities and deliverables include asset condition assessments to support any decisions to retire systems that have reached the end of their design life or changes in asset utilisation.

6. System description

A project shall describe the new or altered system-of-interest, including its high level functions, environment and its functional and physical boundaries, and interfaces.

A project or program of work shall develop appropriate system concept descriptions which describe how it is expected to function from the perspective of different users and systems elements, and how the system elements relate to each other and work together.

6.1. Stakeholder viewpoints

The system description shall describe the system from key user and stakeholder perspectives.

Any project to introduce new or altered systems with significant levels of novelty, complexity and risk, and therefore requiring a systems approach, will have numerous stakeholders. Stakeholders mentioned in section 5.1.1 should be engaged at the outset of the project to define the needs, goals and objectives as part of the problem domain prior to system definition.

Ensure early involvement of the operator and maintainer for the development of a ConOps, OCD, MCD and hazard logs.

6.2. Concept of operations

A ConOps is developed at an enterprise level in the demand and need stage of the system life cycle. The ConOps should describe how TfNSW intends to operate the new or altered system to achieve its needs, goals and objectives documented in long term transport strategies and plans.

6.3. Operational concept

A project shall ensure that a preliminary OCD for the new or altered system is prepared early in the system life cycle before CM gate 1 and to inform and be part of the final business case and BRS. Prior to an OCD the project should have a ConOps to support preliminary business case before CM gate 0.

The OCD should be reviewed and refined as the system definition progresses beyond the BRS and should be finalised when the system solution has been sufficiently defined.

The OCD shall describe how the system will be used and operated over its operational lifetime.

The OCD shall support the business case and associated whole-of-life funding, which includes how much it will cost to operate over its operational lifetime as defined in T MU AM 01001 ST.

The OCD shall be developed as required in T MU AM 06008 ST *Operational Concept Definition* and shall be tailored at the appropriate level of the novelty and complexity of the project.

6.4. Maintenance concept

A project shall ensure that an MCD for the new or altered system is prepared early in the system life cycle, before CM gate 1 and to inform and be part of the final business case and BRS. In general, the MCD should follow an OCD. The maintenance activities stated in the MCD are dependent on their operational service levels stated in the OCD.

The MCD shall describe how the system will be maintained over its lifetime.

The MCD shall support the business case and associated funding, which includes how much it will cost to maintain and support over its operational lifetime. The maintenance concept shall also consider the levels of maintenance required to support the asset (that is, asset location, type, skills and tools) and the associated support attributes such as maintenance policy, maintenance requirements analysis, obsolescence management and disposal requirements. For this reason, the MCD should to some extent contain a disposal concept that considers the transportation and handling, decomposition and processing of the retiring system.

Maintenance concepts defined in the MCD shall align with, and support, operational concepts defined in the OCD.

The maintenance concept shall be developed by the entity responsible for planning in TfNSW and written in accordance to T MU AM 06009 ST *Maintenance Concept Definition*.

7. Systems engineering management

SE management requirements for planning and acquiring new or altered systems include defining and demonstrating management structures for the following:

- organisational structure and responsibilities for SE
- requirements management
- system architecture
- system interfaces
- systems integration
- reliability, availability and maintainability
- safety assurance
- V&V
- electromagnetic compatibility (EMC)
- HFI
- governance and assurance

The party responsible for meeting each requirement may change over the life cycle.

A project shall deploy a whole-of-life SE approach to the planning and acquisition of the new or altered system.

The level of SE shall be scaled and tailored according to an assessment of the novelty, scale, complexity and risk associated with introducing the new or altered system.

This scaling and tailoring should ensure that the level of SE is commensurate with the system complexity, novelty and size. This should also be appropriately addressed in all SE artefacts produced as required by T MU AM 04001 PL *TfNSW Configuration Management Plan*.

The SE management areas described in section 7 will refer to other related standards and guides developed by the ASA. Appendix A shows a hierarchy of these documents in a single diagram.

7.1. System engineering organisation

A project shall define its organisational management structures for SE.

7.1.1. Organisation structure

The activities defined in the SEMP should be allocated to relevant SE roles and should match the capabilities of the organisation responsible for delivering that activity.

7.1.2. Responsibilities

SE related organisational roles shall be mapped to SE processes and activities across the system life cycle and communicated to staff.

This is typically achieved by establishing a responsibility, accountability, consulting, informing (RACI) matrix with SE management processes on one axis and SE roles on the other axis.

An example of a RACI matrix is provided in T MU AM 06006 GU *Systems Engineering*.

7.2. Requirements management

A project shall appropriately plan, manage and implement activities for the management of business and system requirements.

A project shall implement a defined process, responsibilities, structure, tools and deliverables for management of requirements across the system life cycle.

The business needs or goals for new or altered service capability shall be mentioned in the ConOps, OCD and MCD prior to defining the business and systems requirements.

Further guidance on the management of requirements, including definition and analysis are provided in T MU AM 06007 GU *Guide to Requirements Definition and Analysis*.

7.2.1. Business requirements

A BRS shall be produced for CM gate 1 for approval in consultation with relevant stakeholders.

Requirements planning lies on a continuum that can range from concept through to design and who performs the planning will depend on the planning horizon for a particular system.

Stakeholder input for the BRS is typically obtained from the entity responsible for planning and project delivery within TfNSW and the operator and maintainer, if known, of the new or altered system being introduced.

While the planning entity will often produce the BRS, other entities such as project delivery, operator and maintainer may also provide input to support identifying needs, goals, business requirements and system requirements and developing business cases.

The scope of this standard applies to any entity (division or agency) producing these deliverables on behalf of TfNSW as the asset owner.

The entity responsible for producing the BRS shall submit the BRS to CM gate 1 as in T MU AM 04001 PL.

Business requirement specifications shall identify and trace back to informing documents and source documents such as policies, strategies and long-term transport plans. Guidance on developing a BRS can be obtained from T MU AM 06010 GU *Business Requirements Specification*.

7.2.2. System requirements

An SRS shall be produced for CM gate 1 for approval.

System requirements shall be allocated from the SRS into subsystem requirements (SSR) to synthesise and develop detailed subsystem designs as appropriate for the project.

Compliance with this requirement is subject to scaling and tailoring to the level of novelty of the new or altered system. Where type approved equipment is required to be deployed in a standard configuration in compliance with existing engineering standards, then the need for developing a subsystem requirements specification (SSRS) may not be appropriate or required.

Guidance on developing a SRS and SSR is provided in T MU AM 06007 GU.

7.2.3. Requirements management tool

A requirements management tool shall be used to manage the categorisation, allocation, changes, traceability, V&V of business, system and subsystem requirements.

Selection of the type of requirements management tool shall be based on complexity, scale and TfNSW contractual requirements.

The requirements management tool shall be able to exchange requirements information using a common interchange format with TfNSW requirements databases and associated schema. It should also support forward and backward traceability (if working with business and system requirements) and generate reports for the purpose of analysing requirements with stakeholders.

The structure of requirements in a tool is defined in T MU AM 06004 ST *Requirements Schema*.

7.3. System architecture management

A project shall implement management arrangements that define the synthesis and development of system level requirements into a system architecture (functional, physical and geographic). For more information on the system architectural design process and key responsibilities in managing the design refer to T MU AM 06001 GU *AEO Guide to Systems Architectural Design*.

7.3.1. Functional architecture

A project shall describe the functions for the new or altered system and how these relate to operational concept activities, operational capabilities and high-level TfNSW goals.

An example of a functional architecture is provided in T MU AM 06006 GU.

7.3.2. Physical solution architecture

A project shall describe the physical system breakdown structure (SBS) of the proposed new or altered system and describe how the physical solution will be configured.

An SBS is essential for all project types and engineering disciplines to identify operational and support systems, associated asset data and configuration information to pass from designer to builder to tester to operator and maintainer.

Physical system block diagrams shall be used to describe the configuration and integration of the physical assets and systems in relation to each other and to their environment.

The physical solution architecture should also determine whether functions are implemented in hardware, software, including firmware, or by human users.

The creation and management of asset information related to all assets owned and managed by and on behalf of TfNSW across the life cycle is described in T MU AM 02001 ST *Asset Information and Register Requirements*.

An example of a physical SBS and physical system block diagram is provided in T MU AM 06006 GU.

7.3.3. Geographic deployment architecture

A geographic architecture shall be used to describe where the physical assets will be deployed on the TfNSW transport network.

An example of a geographic architecture is provided in T MU AM 06006 GU.

7.3.4. System context and interfaces

The new or altered system shall be described in terms of its context to existing systems and to its operational environment.

An example of a system context and interface architecture is provided in T MU AM 06006 GU.

7.4. System interface management

A project shall implement management arrangements based on a well-defined process, responsibilities, structure, tools and deliverables associated with system interfaces.

A project shall ensure that all system interface requirements under its control are identified, captured and managed.

System interface reviews and checks shall be conducted at appropriate stages of the system design and implementation.

A project shall identify and manage system interface risks and their causes, consequences and controls that may have adverse health, safety or environment impacts on users.

Control and specification of system interfaces shall be via interface control documents (ICDs) and interface requirements specifications (IRS).

The ICD establishes high level interface definition and management responsibilities, whereas the IRS defines the detail on functional, physical, operational and performance criteria for the interface.

For more information on system interface management, refer to TS 10507: 2013 *AEO Guide to Systems Integration*.

7.5. Systems integration management

A project shall implement management arrangements to plan and carry out the safe and controlled integration of all elements of the new or altered system of interest.

On projects where it is not possible to commission into operation the entire new or altered system in one stage a project shall develop and follow a multi-staged systems migration and integration approach.

A project shall identify, plan, schedule and control interim configuration states and migration from one configuration state to the next, up to commissioning of the fully integrated system.

For more information on systems integration management refer to TS 10507: 2013.

7.6. Reliability, availability and maintainability management

A project shall implement management arrangements that define the RAMS process, responsibilities, structure, tools and deliverables.

A project shall consider RAMS performance and how it relates to operational performance for novel systems early in the acquire stage of the asset life cycle, starting with development of the operational concept definition and maintenance concept definition.

A project shall consider human reliability factors as part of the overall reliability of the system.

A project shall use RAMS modelling to appropriately support option selection and development and preliminary system design, to ensure that the new or altered system will meet the stated operational capability and provide value for money over the designed system lifetime.

A project shall consider sustainable operation and maintenance of the new or altered system over the full system life cycle.

For guidance in applying RAM management activities across the life cycle, refer to T MU AM 06002 GU *AEO Guide to Reliability, Availability and Maintainability*.

7.7. Safety assurance

A project shall implement system safety assurance arrangements relevant to the engineering services or products provided.

As appropriate, the determination, planning, management, assurance and governance of program or project hazards and risks affecting project delivery and safety shall be determined and documented.

For guidance in applying safety assurance activities across the life cycle refer to T MU MD 20001 ST.

7.8. Verification and validation

A project shall implement management arrangements based on a well-defined V&V process, responsibilities, structure, tools and deliverables.

A project shall plan V&V activities early in the system life cycle, starting with tracing goals and operational capabilities to the development of the BRS, then to an SRS and finally an SSRS. Throughout the plan stage of the life cycle a V&V plan should be developed (if project is moderately to highly complex) to address all the V&V activities required for the project. During the acquire stage the V&V plan should undergo changes throughout the preliminary and detailed design phases to document the required V&V activities.

A project shall establish and maintain a method of recording all V&V activities and results and trace these to originating requirements.

For guidance on V&V activities, refer to TS 10506: 2013 *AEO Guide to Verification and Validation*.

7.9. Electromagnetic compatibility management

A project shall implement management arrangements for assuring EMC during the specification, design, integration or testing of electrical and electronic systems involving electromagnetic interference (EMI) threats or victims.

A project shall take appropriate steps to plan for and manage the unintentional generation, propagation and reception of electromagnetic energy which may cause unwanted effects such as loss of equipment function or performance, permanent or temporary damage to equipment.

For more information on the management of electromagnetic emissions and susceptibility of devices used in the railway refer to AS/RISSB 7722 *EMC Management*.

For generic requirements that apply to electrical and electronic equipment intended for use in power stations and substations refer to AS IEC 61000.6.5 *Electromagnetic compatibility (EMC) Part 6.5: Generic standards – Immunity for equipment used in power station and substation environment*.

7.10. Human factors integration

A project shall implement management arrangements for assuring HFI during the specification, design, integration or testing of the new or altered system.

For HFI requirements, refer to T MU HF 00001 ST *Human Factors Integration – General Requirements*.

For heavy rail rolling stock additional HFI requirements refer to T HR HF 00001 ST *Human Factors Integration – Rolling Stock*.

HFI guidance is provided in T MU HF 00001 GU *AEO Guide to Human Factors Integration*.

7.11. Governance and assurance

As appropriate, the determination, planning, management, assurance and governance of program or project SE deliverables shall be determined and documented.

For guidance in applying governance and assurance activities across the life cycle refer to T MU AM 04001 PL and TS 10753: 2014 *Assurance and Governance Plan Requirements*.

8. Shared information and records

SE related shared information resources shall be mapped to system life cycle processes and identify which information resource is owned or used by which process owners.

Shared information resources are any databases, registers, logs or other repositories of system specification and development information that may be shared between SE process owners.

Records shall be kept of implementation of SE processes, including traceability to competence of staff managing and using those processes.

A project shall implement management arrangements for the management, assurance and governance of SE artefacts and documents.

The planning and management of SE package handover to the next stage of the system life cycle shall be determined and documented.

9. System engineering management plan

A SEMP shall be developed to manage the overall SE effort required for the project as well as positions of responsibility, major tools and resources to be applied to the project.

A SEMP shall be produced where an assurance argument based on a judgment of significance (JOS) identifies the need.

Where the need for a SEMP cannot be justified, the appropriate scale of SE activities shall be identified in the engineering management plan or project management plan.

The SEMP shall ensure that all SE management objectives are achieved. The SEMP shall be constructed, reviewed and approved by the customer organisation during the concept phase in accordance with the requirements in the contractual documentation.

The SEMP shall define the SE deliverables to be completed prior to each CM gate.

In addition to the TfNSW gateways identified in Figure 1 and Figure 2 a system delivery project may have additional gateways to enhance assurance including intermediate review gates for system definition, preliminary design and final design. Once approved, the SEMP becomes the governing plan controlling the entire SE effort and all technical aspects of the project. The content of the SEMP should be maintained throughout the system design and development effort. Changes to the SEMP shall be reviewed and approved at each formal design review and shall be approved by the customer organisation as this ensures visibility into changes that may expose the project to unexpected risks (such as changes in key personnel).

The SEMP may differ from one project to another depending on the complexity of the system.

The SEMP should generally address the following three key aspects:

- technical project planning and control; describes project tasks to be planned and developed to ensure that project objectives are met including the following tasks:
    - statement of work
    - work breakdown structure
    - organisation
    - task schedules
    - cost, technical performance measurement
    - project design reviews and audits
    - supplier interfaces
    - risk management

- System engineering process; describes the SE process as it applies to the following:
  - system requirements
  - operational and maintenance concept
  - functional analysis and allocation
  - system synthesis and trade-off studies
  - system design
  - integration management
  - test and evaluation
  - specifications (BRS, SRS, and product)
  - standards
- engineering speciality integration; describes major system-level requirements in speciality areas including the following:
  - reliability
  - maintainability
  - human factors
  - systems safety assurance
  - supportability or logistic support
  - EMC
  - producibility
  - quality assurance

The SEMP should cover all of the major SE functions and it may do so by referring to other plans such as the following:

- requirements management plan
- CM plan
- interface management plan
- risk and safety management plan
- programme management plan
- assurance and governance plan
- other specialty engineering management plans (such as RAM, system architecture, safety assurance or HFI management plan)

9.1. System engineering management plan content

Where a SEMP is required it shall include the following sections as a minimum:

- objective or need
- document context and document relationship tree diagram
- system requirements structure
- system scope and boundary description
- system interfaces
- system life cycle and stage gates description
- SE technical processes
- SE organisation, roles and responsibilities
- SE shared information matrix

9.2. System engineering management plan context

The SEMP shall support the following 'parent' plans:

- asset management plan that is scaled to network, line, discipline or asset type depending on the scope of the system to be delivered
- project management plan (PMP), where the level of SE activity is judged to be significant

While the PMP addresses general project management tasks the SEMP outlines technical plans and SE activities that will be used to develop, integrate, test, validate and deploy the system. Developed early in the SE process as a supplement to the PMP the SEMP uses the foundation laid by the PMP to build the framework for carrying out the technical tasks of the project.

The SEMP shall be supported by SE sub plans, appropriate to the level of scope, novelty, complexity and risk of the proposed new or altered system.

On low complexity projects, if some SE activities are to be reduced or excluded altogether, then the project shall produce a coherent assurance argument to justify this decision.

Appendix A Hierarchy of systems engineering documents

Figure 3 shows a hierarchy of SE standards and guides published by the ASA or currently under development.

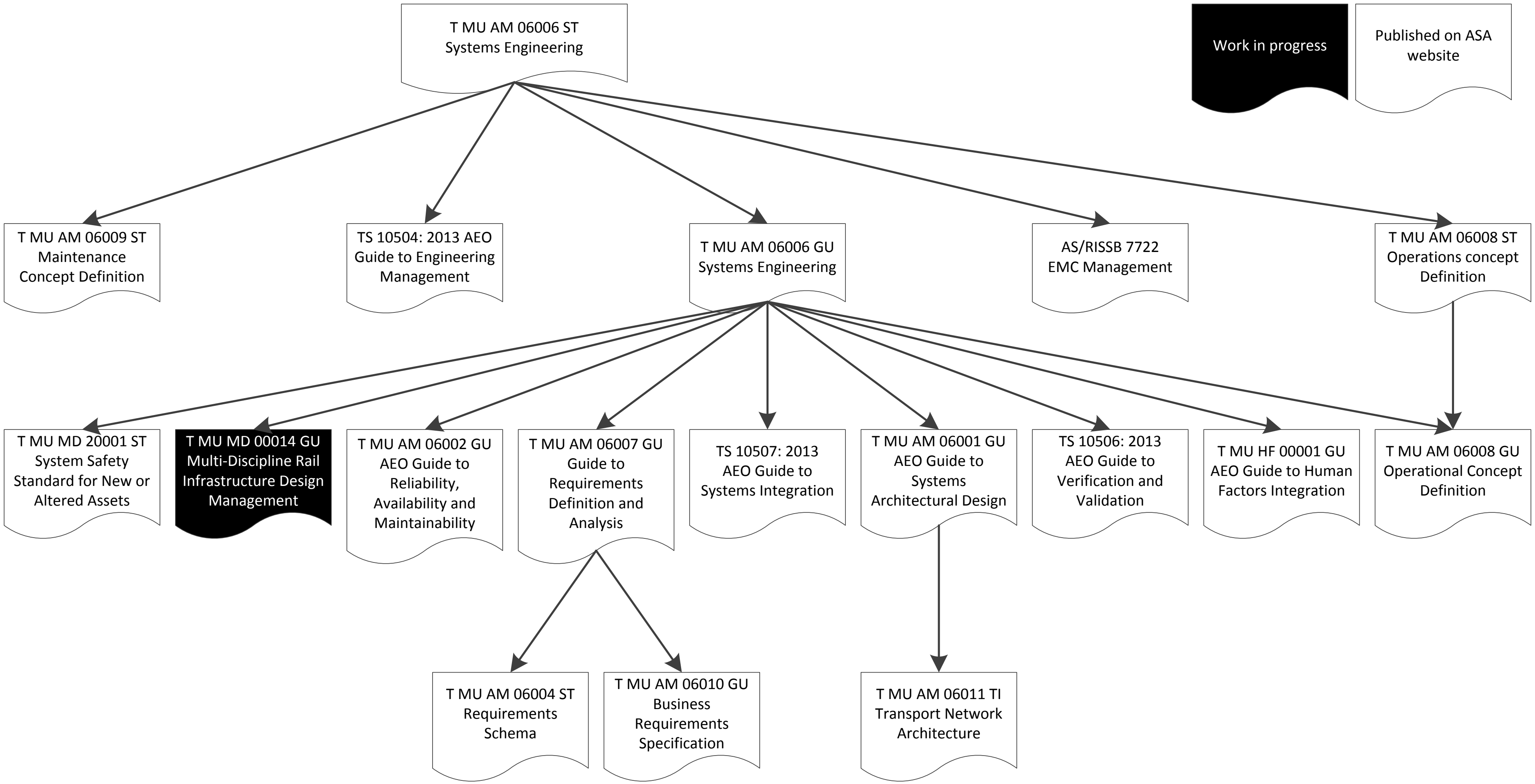

Figure 3 - Hierarchy of SE documents published or work in progress by the ASA

Appendix B Life cycle deliverables and activities summary

The key activities, deliverables and responsible parties for each life cycle stage are shown in Table 1 which assumes the transport project is funded by TfNSW.

Table 1 - Life cycle deliverables and activities summary

Life cycle stage	Key activities and deliverables	Who is responsible
Demand and need	• ConOps • High level business needs • Needs analysis	• TfNSW
Plan – concept	• Transport performance modelling • Transport service design • Preliminary OCD and MCD • Baseline timetable • Concept design • Draft benefits realisation management plan • Draft business case • Draft SEMP • Draft V&V plan • P50 cost estimate • Draft (or strategic) BRS	• TfNSW strategic planning or project delivery • AEOs contracted to provide technical advice in this phase as technical advisors • Transport agencies, operators and maintainers providing services as an AEO under contract to TfNSW may in some cases hold this responsibility, and if not, they should be consulted as key stakeholders in this phase
Plan – specify	• Detailed transport modelling • Updated OCD and MCD • Updated timetable • Updated business case • Updated SEMP • Updated V&V plan • Draft P90 cost estimate • Updated BRS • Preliminary hazard analysis (PHA)	• TfNSW strategic planning or project delivery • AEOs contracted to provide technical advice in this phase as technical advisors • Transport agencies, operators and maintainers providing services as an AEO under contract to TfNSW may in some cases hold this responsibility, and if not, they should be consulted as key stakeholders in this phase

Life cycle stage	Key activities and deliverables	Who is responsible
Plan – procure	• Final OCD and MCD • Approved timetable • Final BRS • Preferred option selection • Draft SRS • Reference design • Tender documentation • Final approved business case • P90 cost estimate • Updated SEMP • Updated V&V plan	• TfNSW strategic planning and project delivery • AEOs contracted to provide technical advice in this phase as technical advisors • Transport agencies, operators and maintainers providing services as an AEO under contract to TfNSW may in some cases hold this responsibility, and if not, they should be consulted as key stakeholders in this phase
Acquire	• Preliminary and detailed design • Bill of materials • Product, process and material specifications • V&V strategies • Site installation and integration • Review benefits realisation plan • Unit, subsystem and system level testing • Operational readiness and validation • Safety assurance report	• TfNSW project delivery • Any other asset delivery organisation that is established by TfNSW, including acquisition projects managed by transport agencies or operators and maintainers • AEOs contracted to provide design, supply, manufacturing or fabrication, site installation, integration, testing and commissioning services to TfNSW in this life cycle phase
Operate and maintain	• Asset condition assessment • Asset maintenance plan • FRACAS • Carry out asset maintenance and logistic support against asset maintenance plan • Perform modifications • Identify failures during operational use • Operational safety argument • Review benefits realisation plan	• Transport operators and maintainers providing services under contract to TfNSW • AEOs sub-contracted to provide asset maintenance services in this life cycle phase

Life cycle stage	Key activities and deliverables	Who is responsible
Dispose	• Identify reasons for potential retirement • Identify potential retirement methods for the system • Identify design issues that may arise as a result of disposal	• TfNSW • Transport operators and maintainers • Other asset operation and maintenance organisations, which could be AEOs, who make performance-based decisions when an asset is retired from service • Other stakeholders such as; secure IT asset disposal, data centre service providers and environmental agencies