



Systems Engineering and Project Management (SEPM) Joint Working Group

Integrated Life Cycle Representation

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Summary

This paper describes the work that has been undertaken within Workstream 8 to develop an integrated SEPM Vee-model. This is a conceptual model that combines Systems Engineering and Project and Programme Management perspectives in order to promote a common view of the processes and lifecycle required to deliver enduring beneficial change.

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The following document represents the thoughts and conclusions of the Systems Thinking SIG and not necessarily the views of the APM or INCOSE UK. It is intended to assist Project, Programme and Portfolio Management and Systems Engineering practitioners wishing to explore concepts and ideas around Systems Thinking in P3M and to stimulate discussion on the subject. Feedback on the contents of this paper should be sent to the Systems Thinking SIG (SystemsThinkingSIG@apm.org.uk). It therefore does not constitute any formal position (or liability arising) on the part of the International Council for Systems Engineering (INCOSE), INCOSE UK Ltd. or the Association for Project Management (APM), nor should any formal endorsement by these bodies be inferred.

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1. Introduction

Purpose and Scope

In 2013 the UK chapter of the International Council on Systems Engineering (INCOSE UK) and the Association of Project Management (APM) founded a Joint Working Group to realise this potential of collaborative working between Project Management (PM) and Systems Engineering (SE). This Joint Working Group was arranged into several Workstreams as shown in Table 1, of which Workstream 8 was set up to look at the processes and life cycles involved across the two disciplines.

Table 1: Workstreams within the APM/INCOSE Joint Working Group¹

What are the benefits?	
WS 1	Compelling value proposition
How to deliver the benefits?	
WS 8	Processes and life cycles
WS 4	Roles and responsibilities
WS 6	Competency framework
WS 7	Education and training
How to promote the benefits?	
WS 2	Communication
WS 3	Guidance material
WS 5	Case studies

There are 3 main Objectives of Workstream 8 “Processes and Life Cycles”:²

1. To identify where SE and PM models, approaches and ways of working overlap and are complementary, and identify the nature of the relationships between the two disciplines;
2. To develop (where appropriate) a set of unified processes and life cycle models (or look to utilise existing unified models and processes);
3. To communicate, review and exploit these processes and life cycle models amongst the PM and SE communities.

¹ For further details on the APM/INCOSE JWG on SE/PM Integration, see JWG document “Aims and Objectives”, Version 1

² See APM/INCOSE JWG on SE/PM Integration, “Workstream 8 Project Brief”, Version 1, September 2013

This document follows on from the work undertaken towards Objectives 1 and 3 and directly addresses Objective 2 from a life cycle perspective. When looking at life cycles it is worth noting that we are considering any change situation, including the introduction or modification of products or capabilities. The purpose of this document is to form a framework around which key messages and information can be captured related to the subject of life cycles within the PM and SE environments. This includes information in support of the other JWG Workstreams.

This guide is not intended to compare and review individual life cycles or processes. This has been undertaken in the accompanying publications “**Guide to Life Cycle Models**” and “**Guide to SE and P3M Processes**” that addresses Objectives 1 & 3. Nor is it intended to propose a single, unified life cycle model; rather it is offered as a framework to promote better understanding across the two disciplines.

Terminology

The term “life cycle” can also be denoted by “lifecycle” or “life-cycle”. In this document the term “life cycle” is used throughout except where providing a direct reference to a source that uses a different form.

The term P3 is used to denote Project, Programmes and Portfolios (as defined within the APM Body of Knowledge), and P3M denotes Project, Programme and Portfolio Management. Where the discussion only refers specifically to Projects and Programme Management, the term PPM will be used. SE is used to denote Systems Engineering in the context of approaches, models, processes and ways of thinking.

Key References

Unless otherwise referenced, information is taken from the INCOSE System Engineering Handbook (SEHBK) v3.2.2 (2011) or the APM Body of Knowledge (APMBOK) 6th Edition (2012).

Other key references also include information from the ISO Standard on Systems Engineering (ISO15288:2015) and the ISO Standard on Project Management (ISO21500:2012)³. Use has also been made of the information contained within the Guide to the SE Body of Knowledge (SEBOK) (currently at v1.3)⁴.

³ Note that ISO21502 (Project and Programme Portfolio Management) and ISO21504 (Programme Management) are currently in draft form.

⁴ *Guide to the System Engineering Body of Knowledge*, v1.3, available at <http://www.sebokwiki.org/>

2. Integrating P3M and SE Perspectives

The Combined Change Viewpoints

Systems Engineering (SE) and Project, Programme and Portfolio Management (P3M) share common values in thinking about complex problems, delivering enduring beneficial change (or transformation), and bringing together disparate disciplines. In effect they present different perspectives on change, as illustrated in Figure 1.

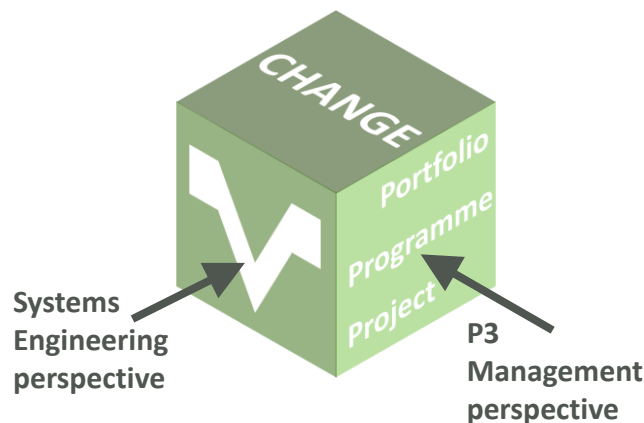


Figure 1: The Different Perspectives on Change

The Vee-model as a Conceptual Life Cycle Representation

The Vee- (or V-) model is a graphical representation of the software or systems engineering lifecycle. It was first used as a basis for software development in Germany in the early 1990s and later adopted by software and system engineering communities in the UK and US. In Germany it provides the basis for the official project management methodology of the government and therefore is roughly equivalent to PRINCE2. However, in the UK and US it is regarded as a higher-level conceptual model. This vaguer interpretation allows for iterations across and between the various stages so that, despite appearances, the Vee-model does not imply any particular development approach, i.e. waterfall.

The INCOSE Systems Engineering Handbook [SEHBK], p.27, explains that the Vee-Model “highlights the need to define verification plans during requirements development, the need for continuous validation with the stakeholders, and the importance of continuous risk and opportunity assessment.” These objectives are shared by the project management community.

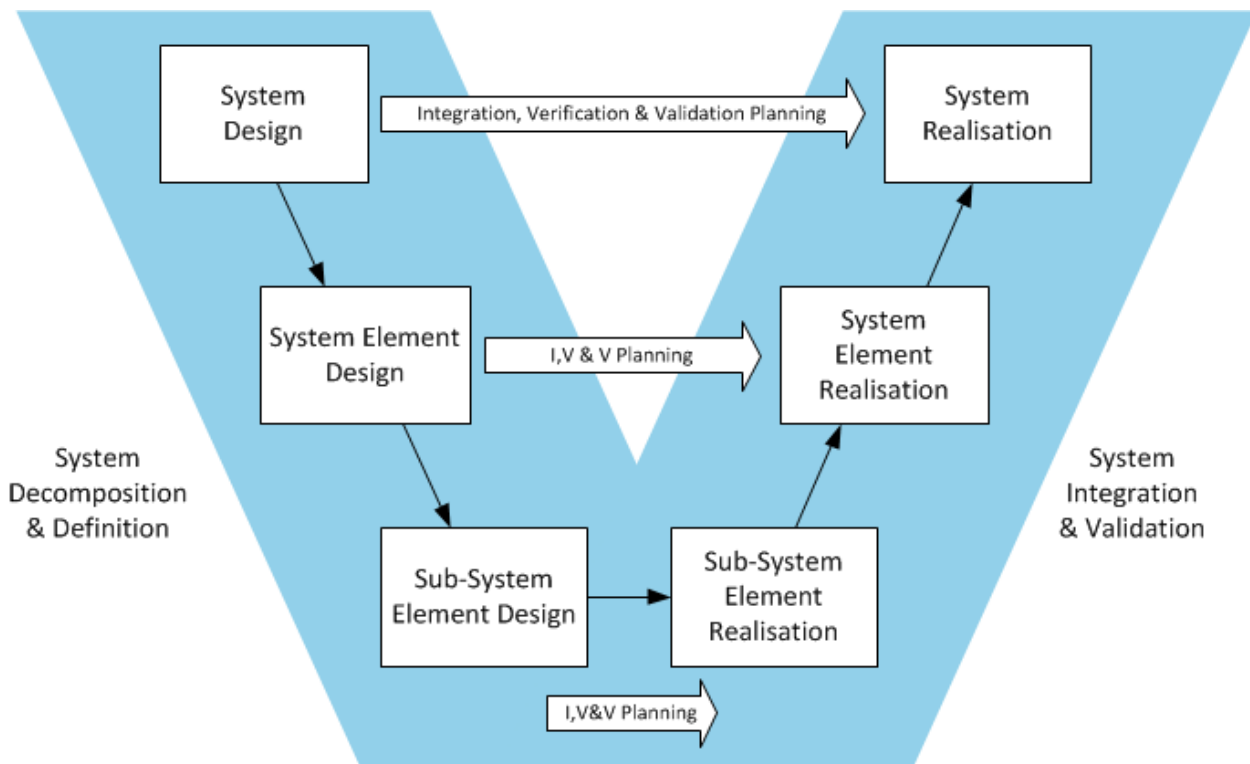


Figure 2: Representation of the INCOSE Systems Engineering Handbook Vee-model

This version of the Vee-model emphasises the hierarchical decomposition of the system into system elements and their definition on the left hand side of the Vee, and the integration, verification and validation of these system elements on the right hand side of the Vee. A key concept of the model is the alignment between the activities on both sides of the Vee, particularly in respect of Integration, Verification and Validation Planning.

In this paper, we extend this conceptual Vee-model by incorporating elements of PPM alongside the SE elements outlined in Figure 2 to produce a combined SEPM model that can be used to improve communication between project Managers and System Engineers, and promote a common understanding.

The Extended Programme System Life Cycle

Depictions of elements of Programme Management processes and activities also exist as a Vee Model. *Managing Successful Programmes*[®] (MSP[®])⁵ in its 2007 Version depicted the Benefits strategy in a limited Vee model arrangement, and this was further advanced in the 2011 Version.

This arrangement was extended to embody the concept of a programme as a system of systems (with the individual projects considered as systems or sub-systems) to provide a different perspective on programme management principles. This extended representation as shown in Figure 3, was included in various APM events, including the ProgM Conference in 2013⁶ and the “Introduction to Programme Management” element of the “APM Presents...” Conference in 2014⁷.

⁵ MSP[®] is part of the Global Best Practice Suite from Axelos Ltd. (www.axelos.com)

⁶ Refer to “More for Less: ProgM Conference 2013” (<https://www.apm.org.uk/news/apm-more-less-reflections-progm-conference>)

⁷ Refer to “Joining the Dots: An introduction to Programme Management” (<https://www.apm.org.uk/news/risk-and-programme-management-joining-dots-apm-presents>)

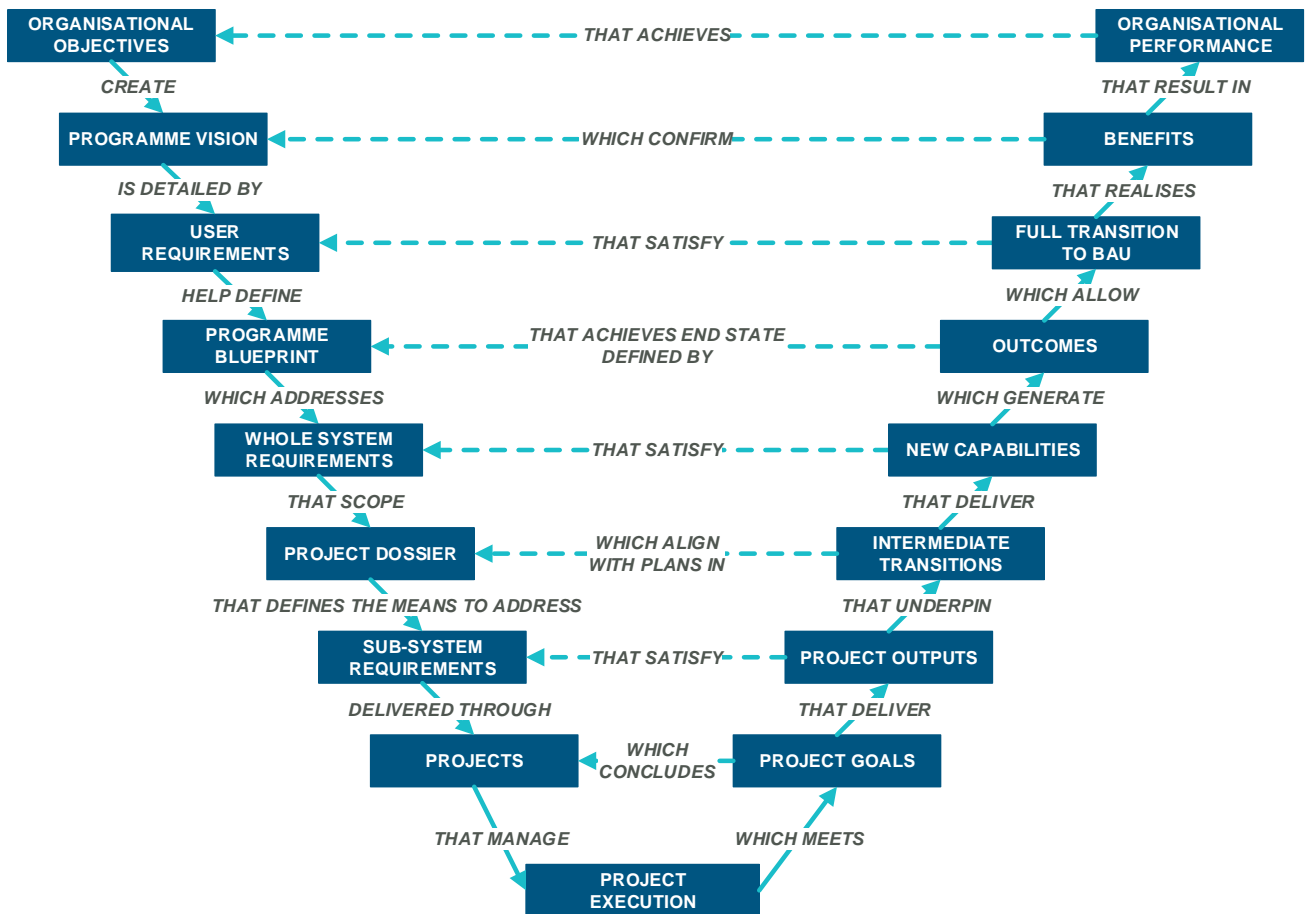


Figure 3: The Programme Vee Life cycle Model

Integrating the P3M and SE Life cycles

To demonstrate how Programme and Project Management (PPM) and Systems Engineering (SE) interact, and the benefits of integrated thinking, the APM/INCOSE Joint Working Group has extended the well-known Systems Engineering Vee-model to incorporate Programme Management and Project Management aspects.

In the sections that follow separate PPM and SE perspectives or ‘views’ are first introduced and then combined to create the SEPM V-Model.

3. The Project Management Perspective

The project management perspective draws on PPM terminology used in the APM BOK, including the processes shown in the pink text. The top part of the diagram relates to the programme-level and the lower part the project-level. In the model, the programme-level is equivalent to the enterprise- or capability-level and encompasses the development of the **Programme Vision** (on the left hand side of the Vee) which maps to the anticipated, and hopefully later realised, **Benefits** (on the right hand side of the Vee), the **Programme Blueprint** which captures the ‘as-is’ to ‘to-be’ transformation and maps to the **Outcomes** which represent the new state, and the **Programme Plan** for delivering and then combining **Capability Elements** to form an **Operational Capability**. At the project-level, **Project Plans** are used to generate **Outputs**, which may constitute **Capability Elements** at the ‘programme-level’.

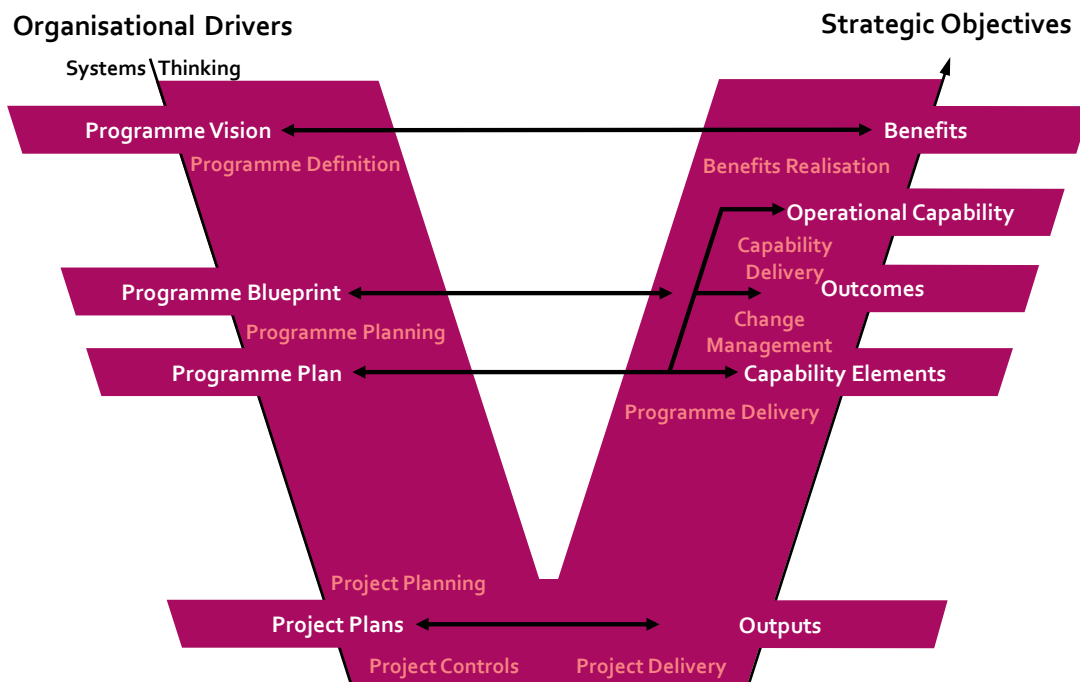


Figure 4: The PPM Perspective on the SEPM Vee-model

4. The Systems Engineering Perspective

This section presents the systems engineering perspective. Note that the ISO/IEE 15288:2015 Technical Processes, adopted by the INCOSE Systems Engineering Handbook (SEHBK), are shown in the light blue text.

It is essential at the outset that comprehensive System Thinking is conducted to ensure the right problem is being addressed. This starts during the Business Analysis stage, applied to the initial 'programme vision'. Systems Thinking is progressed throughout the SE process; applied with varying degrees of sophistication and rigour dependent on the level at which being considered to ensure that wider factors which could undermine the programme, or create emergent issues further into the life cycle are anticipated.

A key concept is that **User Requirements** in combination with the **Operational Architecture** (on the left hand side of the Vee) map to, and provide the basis for, the validation process and result in a **Validated System** (on the right hand side of the Vee), whilst **System Requirements** map to, and provide the basis for, the verification process, and result in a **Verified System**. More specifically:

- Verification tests conformance to **System Requirements**, i.e. that the system has been built right;
- Validation tests conformance to **User Requirements**, i.e. that the right system has been built.

To complete the SE perspective, the **System Architecture** defines the **System Elements** which are implemented and how these are combined (integrated) to produce an **Integrated System**.

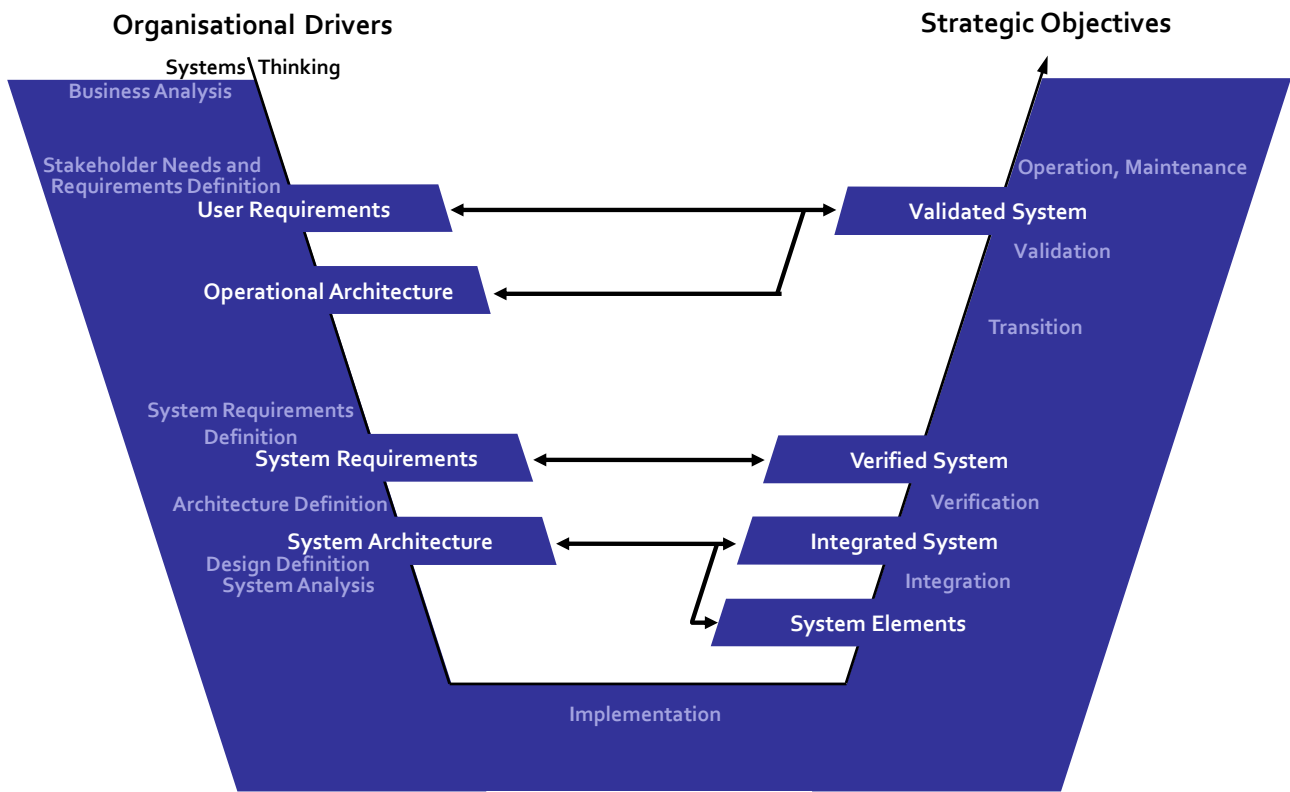


Figure 5: The SE Perspective on the SEPM Vee model

5. The Integrated SEPM Vee-model

In this section we combine the PPM and SE perspectives into a single, integrated model.

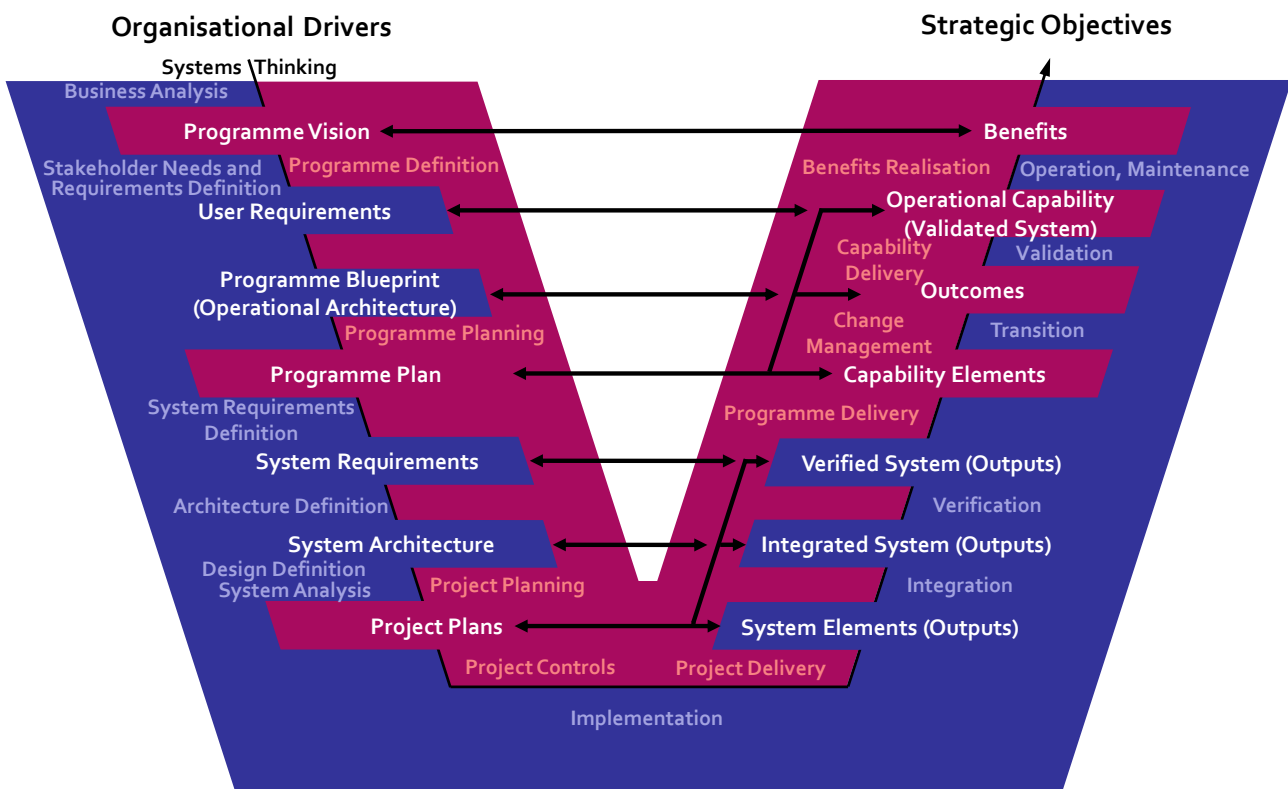


Figure 6: The Integrated SEPM Vee-model

The colours previously used in the two separate perspectives are retained so that the aspects that those from the PPM community are likely to be most familiar with are shown against a purple background, whilst the Systems Engineering aspects are shown against a blue background. The aim has been to combine both perspectives to highlight areas of overlap and where the two views complement or enhance each other; what we term ‘fusions’. Note that (Project) **Outputs** has been replaced by **System Elements** so that **Project Plans** now map to **System Elements** (and therefore mirrors the way that **Programme Plans** map to **Capability Elements**).

The term system is used to encompass what may be an equipment-focused, product-focused or service-focused system. A key point is that an equipment-focused system consists not only of the equipment itself but also the *capability* to operate, support and ultimately dispose of the equipment (in other words, it includes what are often termed no-equipment Lines of Development). Similarly, a product-focused system is not just the new or enhanced product, but the enduring *capability* to reliably manufacture, assemble, test and support that product via a number of organisational-level functions and processes. Finally, a service-focused system provides the *capability* to sustain a new or enhanced business operation. Furthermore, the

capability that has been developed may be used to deliver a single event (such as an Olympic Games), a time-limited mission (such as an overseas military operation) or an ongoing business operation (such as provision of a public transportation service or high-volume manufacture).

Different organisations and industries may use different terms such as Capability Acquisition, Transformational Change or New Product Introduction but all of these can be represented by the above model with, if desired, only a minimal amount of tailoring and changes in terminology to suit the particular context.

The combined SEPM Vee-model illustrates areas of overlap between the two perspectives, and also areas where the two areas complement or enhance each other; our fusions. Throughout, a Systems Thinking approach should be iterated, as the nature of the programme vision and benefits realisation aspect can vary over time, or may require adjustment.

Fusions

There are two areas of overlap where the two perspectives are clearly looking to achieve the same thing but use different terminology, i.e.

- **Operational Capability (PPM) / Validated System (SE)** – these are equivalent terms used to describe the delivered system within its operational context. However, this is also an area of enhancement since the use of SE Requirements Elicitation methods and techniques to generate **User Requirements** that are complete, consistent and unambiguous and the subsequent validation of the delivered system against these requirements ensures that the delivered **Operational Capability** meets the user’s needs and can be contracted against;
- **Operational Architecture (SE) / Programme Blueprint (PPM)** – both perspectives are looking to describe the future **Operational Capability**.

Enhancements

There are also a number of areas where the two perspectives complement and enhance each other, i.e.

from the PPM perspective:

- Systems Engineering expands the Project Planning / Solution Development / Project Delivery lifecycle by providing engineering rigour to the specification, design, implementation and testing of project outputs;
- **User Requirements** provide the basis for validating that the delivered **Operational Capability** meets the user’s needs.

and from the SE perspective:

- Programme and Project Management helps to establish the ‘business context’ within which the Systems Engineering activities are undertaken. Iterative consideration of the context throughout the life cycle is vital, since if aspects of this change functions, and thus requirements, change together with concomitant downstream validation aspects.

6. Integrated Perspective

This section describes a further, integrated, described on the SEPM Vee-model.

The **Programme Vision** helps to define the **Benefits** that a programme is required to deliver to help the organisation achieve its **Strategic Objectives** that are derived from its **Organisational Drivers**.

User Requirements capture the agreed needs, constraints and expectations that the realised **Operational Capability** is required to satisfy. This is subsequently validated against the **User Requirements** to ensure that “the right system has been built” resulting in a **Validated System**. It is reiterated that comprehensive System Thinking is conducted from the outset to ensure the right problem is being addressed – which will then be ‘built right’. Programme Definition also involves developing the Enterprise-level **Operational Architecture** (or **Programme Blueprint**) that defines how the various **Capability Elements** will be combined to provide an enduring or sustained **Operational Capability**. More specifically, the **Programme Blueprint** defines the **Outcomes** that the programme is required to deliver as a result of organisational change. In each case there are multiple facets (the Lines of Development) that are all required to ensure that the equipment, product or service becomes embedded within the organisation as ‘business as usual’.

The **Programme Plan** defines the **Capability Elements** which the programme will deliver, and also scopes the projects and other activities that will be co-ordinated by the programme. This involves defining the **System Requirements** and **System Architecture** that specify the behaviours and characteristics which the proposed system must exhibit.

The **Project Plans** define how **System Elements** will be implemented and integrated to produce an **Integrated System** that is then verified against the **System Requirements** to ensure that “the system has been built right” – a **Verified System**. This is then transitioned and validated at the programme-level to provide the **Operational Capability**. Note that ‘no one size fits all’ so:

- a) The boundary between the programme-level scope and project-level scope may vary from organisation to organisation, or from programme to programme. For example, the generation of **Project Plans** may be considered to be a programme-level activity, part of the project itself, or perhaps (from an external supplier perspective) as the Bid Phase prior to project execution and delivery. Similarly, the scope of projects may vary on the right hand side of the Vee-model, and deliver anything from a single **System Element** to an **Operational Capability (Validated System)**.
- b) Programmes may be sub-divided into Tranches – groups of projects designed to deliver a step change in capability;
- c) The Requirements / Architecture / Plans structure on the left hand side is recursive, and may be repeated a further time to show how a Sub-system Requirements, Sub-system Architecture and Work Package Plans are generated, and lead to the implementation of Sub-system Elements that are integrated and verified to produce **System Elements**.

In all this the key points are, from a PPM perspective, that a project is likely to be part of a larger programme, and from a SE perspective, that the System (or System Element) developed at the project-level sits within this wider context.