INCOSE

INCOSE PUBLICATIONS

ASIA-OCEANIA SYSTEMS ENGINEERING CONFERENCE

Driving SoS Engineering

A Pragmatic Typology

INCOSE AOSEC · 2025

AUTHORS

Jaci Pratt

PUBLICATION DATE

July, 2026

SUBMISSION #

13

Driving SoS Engineering: A Pragmatic Typology

Jaci M Pratt
University of Adelaide and **Defence Science & Technology Group**
North Terrace, **West Avenue,**
Adelaide SA 5005 **Edinburgh SA 5111**
jacolyn.pratt@adelaide.edu.au

Abstract

Many typologies exist to support the understanding and engineering of systems and software; however, a typology to specifically guide and direct the engineering of Systems-of-Systems (SoS) is not evident. An extensive multi-disciplinary literature review of SoS-relevant typologies was used to address this gap, followed by a comprehensive qualitative analysis to identify the dimensions and categories of common use and greatest impact for SoS Engineering (SoSE). Based on grounded theory, clustering analysis, and design criteria, a set of key axes, dimensions and categories was synthesised to form the SoSE typology. The five axes of complexity, context, capability, SoS focus and management focus, with their primary dimensions, provide a high-level structured schema decomposable into the proposed categories or refined as needed. Careful tailoring of the typology to the specific situation and system of interest is recommended with frequent review. This multi-dimensional typology directly supports SoSE and management teams to recognise problems, options and risks in a timely and practical manner throughout the lifecycle by comprehensively understanding and monitoring the whole space i.e. the SoS, its constituent systems (CS), context and problem.

Keywords

System-of-Systems, SoS, System-of-Systems Engineering, SoSE, typology, framework, multi-disciplinary.

Introduction & Background

Research into SoS Engineering (SoSE) approaches and tools for application in the Australian Department of Defence has been occurring over many years. The need for improved methodologies to deliver complex and integrated capabilities has grown with increased economic and strategic pressure. Frameworks, typologies and taxonomies are key research classification tools used across most disciplines to structure data collection, analysis and decision making. Their inherent structure supports systematic approaches and improves shared awareness. Numerous taxonomies and typologies have been developed to aid systems and software engineering development processes. In System-of-Systems (SoS), the most prevalent typologies differentiate SoS from systems to induce alternate methods and thinking. However, a SoSE typology should not only support classifying the system of interest as a SoS but also improve understanding of the complete SoSE space and its development and evolution. As a single typology does not exist currently to comprehensively address this scope, this research seeks to identify key typologies and elements from different disciplines and develop a broad and multi-dimensional typology to support SoSE directly. The work discussed here builds on initial efforts exploring a set of classifying dimensions for SoS (Cook & Pratt, 2016).

This paper describes the importance and use of typologies, guidance on their development and the criteria for veracity and integrity. A systematic account of the significant multi-disciplinary literature review undertaken to identify typologies relevant to SoSE is then presented. The analysis of these typologies and the design of a SoSE-specific typology is provided. Finally, an explanation of the developed typology and its practical application is supplied.

Methodology

This study employed qualitative research analysis and constructive design methodologies. A comprehensive literature search of frameworks and typologies identified the key literature concerning the development and use of typologies and analytical frameworks, with emphasis on social, complex, defence and SoS areas. The review also identified typologies in use and shortlisted these by relevance to the study area, with detailed examination and data extraction conducted for selected texts. Captured information included their purpose, general description, components and subcomponents, for detailed qualitative and comparative analysis. Identified typologies were classified by broad application type (theme) and coded using a basic grounded theory method to understand purpose, area of application and level of detail. The relevance to SoSE was assessed to ascertain the typologies of greatest impact and those that could be discounted. This comprehensive coding enabled clustering and more detailed comparison of typologies and their components to identify key areas. The assessment and cluster analysis provided the knowledge to enable design of the SoSE typology.

Typology Guidance

Frameworks, typologies, and taxonomies are distinct forms of classification tools, each with nuanced differences in scope and intended function; despite foundational differences, these terms are occasionally used interchangeably. A taxonomy classifies “phenomena into mutually exclusive and exhaustive sets with a series of discrete decision rules” (Doty & Glick, 1994:232); whereas a typology is “an organized system of types that breaks down an overarching concept into component dimensions and types” (Collier et al., 2012:2 Appendix). Distinct variations are evident in the grouping constructs (empirical vs conceptual) and placement method (definitive rules for complete coverage vs open methods) (Doty & Glick, 1994; Kluge, 2000; Smith, 2002). Typologies are more suited to complex, subjective, abstract and adaptive constructs.

Typologies and frameworks both support the understanding of complex phenomena, identify concepts, assist measurement, organise knowledge, guide research and make the implicit explicit (Doty & Glick, 1994; Collier et al., 2012; Kanger 2024; Partelow 2023). While not resolving problems, they provide insights and highlight aspects that merit deeper investigation (Alford & Head, 2017). Despite scepticism regarding their qualitative nature and opacity of construction, rigorously designed typologies are vital for addressing complexity and multidimensionality in scholarly analysis (Collier et al., 2012). A structured approach to typology development is recommended to address these criticisms. This includes articulating a clear purpose covering the domain/discipline, research paradigm, philosophical stance, and intended contribution (Kanger, 2024; Partelow, 2023). Dimensions and categories must be logically derived, clearly explained, and meaningfully connected to the overarching concept (Collier et al., 2012; Doty & Glick, 1994; Kluge, 2000). Assumptions, intended use, and comparative value relative to extant typologies should be explicit (Doty & Glick, 1994; Partelow, 2023). Specific guidance on formation of typologies is found in Collier et al.’s template (2012) and Kluge’s four-stage construction process: define dimensions, group cases, identify relationships, and characterise types (2000).

Effective typologies are characterised by systematic and transparent construction, with well-defined dimensions and categories that maximize internal homogeneity and external heterogeneity (Babbie, 2007; Kanger, 2024; Kluge, 2000). Clarity in naming and meaning is essential, given the interpretive nuances of language (Babbie, 2007; Collier et al., 2012; Kanger, 2024). Parsimony is encouraged to maintain analytical manageability without oversimplifying complex phenomena (Doty & Glick, 1994). Ongoing review and refinement ensure purpose is achieved as knowledge and meaning evolve with the Hermeneutic Cycle

(Kaplan, 1964; Babbie, 2007). Most importantly, the scope, aggregation, and level of detail must be tailored to the inquiry purpose and domain to provide practical and useful insights (Alford & Head, 2017; Babbie, 2007; Collier et al., 2012; Kanger, 2024). In summary, there are four key characteristics of a good typology:

- Clarity and conciseness
- Rigour and logic
- Structure and organisation
- Tailored and purpose-driven

Typology Literature Review

The comprehensive review obtained literature from systems engineering, business and strategic management, sociology, system-of-systems (SoS), and defence domains. Sources were selected for their provision of information on development and application, as well as information on the schema itself. An initial pool of over 200 references was shortlisted by relevance to the study area, with detailed examination and data extraction conducted for selected texts. The distinct themes observed during initial coding provided a clustering of relevant typologies allowing a basic level of comparison and clustering. While conducted for all themes, only several examples of the basic clustering are provided in the Literature Review discussion (Table 1; Table 2; Table 3) with the more detailed typology comparison and analysis discussion provided later. This section presents an overview of the typologies by theme and discusses their initial comparison and applicability to SoSE.

Systems and SoS Theme

Typologies have been applied to understand, develop and manage systems based on a variety of perspectives and applications. Several authors have offered typologies to characterise a system; each taking a very different approach – *systemness* criteria, fundamental systems principles and systems characteristics (Dori et al. 2020; Keating et al. 2001; Moses, 2004). Many of these dimensions are non-functional in their nature and often conceptual i.e. self-organisation, complementarity, complexity, emergence, holism, and modularity.

Typologies based on systems hierarchies, focused on size, scale and relationships, are used to determine the most relevant engineering methodologies/techniques, across all of which strong alignment was evident (Boulding, 1956; Cook et al. 1999; Flood & Jackson, 1991; Hitchins, 2007; DeLaurentis & Crossley, 2005; Mansouri et al. 2010; Karcanias & Hessami, 2010). Other typologies take a functional approach to aid the understanding of systems performance (Beer, 1972; Boulding, 1956; Calvano & John, 2003; Karcanias & Hessami, 2010; Keating & Katina, 2012; Lewis, 2002; Jordan, 2003). These typologies also take different perspectives and application domains; however, they all involve structure, connectivity, interactions and context. As SoS are also systems, typologies for engineering and understanding systems should provide insights with appropriate reflection on their applicability and basis for the SoS context.

Numerous SoS-specific typologies have been developed as research and interest in the area has increased. As with all other themes, well-known typologies in many forms have been developed to describe the characteristics of a SoS (Maier, 1998; Dahmann & Baldwin, 2008; Kemp et al. 2013; Boardman & Sauser, 2006; Firesmith, 2010; Kaplan, 2006; Lewis et al. 2008). Other typologies have captured the differences between systems and SoS to determine the drivers for SoSE (Gorod et al. 2008; ISO/IEC/IEEE 21840:2019). Various typologies to support design, analysis and engineering have been developed (Kinder et al. 2012; Tekinerdogan, 2019; Smith et al. 2010; Henrie & Delaney, 2005; Mostafavi et al. 2011; Gideon et al. 2005; Kazman et al. 2013). Many of these propose dimensions relating to the interactions, stakeholders, purpose, domain, and governance of the SoS and emphasise interdependence between dimensions. A comparison of the dimensions of many of the non-characterising SoS typologies is presented in Table 1; showing compelling overlaps in many areas.

	SoS Attributes [1,2] & Drivers [1,3]	System-of-Interest dimensions [4]	SoS Classification [5]	Analytical SoS Frameworks [6, 7]	Innovation SoS Framework [8]	SoS Taxonomy [9]	SoS Context [10]

Governance & Authority	management [1] authority [1] centricity [1] management framework [1]	nature of CS relationships [4]	governance [5] logical configuration [5]	element relationships [6]	institutions [8] networks [8]	operational [9]	integration purpose [10]
Context & Purpose	purpose [1] goals [1]	concept of operation/use [4]		element relationships [6]	context [8]	acquisition [9]	
Stakeholder & Organisation	stakeholder nature [1] goals [1]	system owners & operations [4]	logical configuration [5]	socio-technical aspects [6]	players [8] networks [8]		
Domain/ System type		CS types [4]	application domain [5] system element type [5]	domain & its nature [7]	categories [8]	domain [9]	
Dynamicity	boundaries [1] problem [1]	variability [4]	technological adaptation [5]	desired emergence [6]			development context [10]
Lifecycle	lifecycle [1] timeframe [1]	lifecycle [4]				acquisition [9]	
SoS type	operations [2]	classification [4]	management [5]			operational [9]	
CS Interactions	structure [1] centricity [1]	CS interaction medium/type [4]					integration purpose [10]
Ownership	ownership [1]	system owners & operations [4]				acquisition [9]	
Resources	resources [2]				networks [8] resources [8]	acquisition [9]	
Scope	focus [1]			scope [7]			scope [10]

Reference Key: [1] ISO/IEC/IEEE 21840:2019; [2] ISO/IEC/IEEE 21841:2019; [3] Gorod et al. (2008); [4] Kinder et al. (2012); [5] Tekinerdogan (2019); [6] Smith et al. (2010); [7] Henrie & Delaney (2005); [8] Mostafavi et al. (2011); [9] Gideon et al. (2005); [10] Kazman et al. (2013)

Table 1. Comparison of SoS Typologies.

Complexity Theme

Complexity is an essential concept that is receiving increased attention in systems science and engineering. Many typologies have been developed to address aspects of complexity from the conceptual and generic to the practical and specific. Generic classifiers often view complexity as continuous variables or form bands across a spectrum of continuity. These include the common simple-complicated-complex-chaotic-disorder (Bakhshi et al. 2016; Hallo & Gorod, 2019; Kurtz & Snowden, 2003; Sheard et al. 2021), detail-dynamic (Senge, 1990; Calvano & John, 2003), disordered-organised (Weaver, 1948), subjective-objective (Sillitto, 2009), and low-high (Kovacic et al. 2008).

More-detailed typologies have been developed to understand the behaviours of complex systems and support activities to address them (Calvano & John, 2003; Cook et al. 1999; Firesmith, 2010; Flood & Jackson, 1991; Jackson & Keys, 1984; Karcanias & Hessami, 2010; Sheard & Mostashari, 2011). These primarily focus on dynamicity, heterogeneity, the interactions between systems elements, and the structure and size of the system and its elements. Some dimensions found in only one or two typologies were socio-political complexity, technological complexity, environmental interactions and the number of requirements or missions. Table 2 shows the most correlated dimensions across references fit into five areas: connectivity, dynamicity, structure, diversity and size.

Numerous typologies to understand the complexity inherent within projects and its impact on delivery have also been established (Stevens, 2008; Helmsman, 2012; Potts et al. 2020; Bakhshi et al. 2016). These are principally used to compare projects or assess the effort and risk expected therein, often via the use of spider diagrams. Their dimensions are much broader in coverage given the need to understand the impacts of complexity across all areas related to the design and delivery of engineered systems.

	System Complexity [1]	Complexity Types [2]	Complex Problems [3]	System attributes [4]	System features[5]

Connectivity	number & complexity of interactions	structural complexity connectivity	interactions & level of organisation between them	# interactions & nature between sub-systems	interactions (& their strength)
Dynamicity		dynamic complexity (short-/long-term)	evolution	evolution behaviour	formation/ operation (& their timescales)
Structure	number & complexity of subsystems	structural complexity size	number of elements within systems	number & attributes of subsystems	
Diversity	heterogeneity	structural complexity inhomogeneity			diversity/ variability
Size	system size	structural complexity size			elements (and their number)

Reference Key: [1] Firesmith (2010); [2] Sheard & Mostashari (2011); [3] Jackson & Keys (1984) and Flood & Jackson (1991); [4] Cook et al. (1999); [5] Calvano & John (2003)

Table 2. Comparison of Complexity (or Project Complexity) Typologies.

Significant commonality was observed across many of the typologies with dimensions addressing management, technological, stakeholder, organisational and environmental aspects, as well as system behaviour, purpose, scale and scope.

Complexity is acknowledged as an important influencing factor in the engineering of systems and more so for SoS, where complexity is permanently resident in some form. Understanding the degree of complexity, how and where it manifests within the system(s) of interest, and the implications of this complexity on design, development, operation and management is vital for successful SoSE.

Problem Theme

Understanding the problem space is considered vital for effective engineering and successful solutions (Boulding, 1956; Jackson & Keys, 1984). Different typologies have been proposed over the years, with some remaining active and compelling in the systems and engineering community. The most cited, containing dimensions of problem complexity and stakeholder nature (Jackson & Keys 1984; Flood & Jackson 1991), is used to determine the most appropriate system intervention. Focusing on *wicked* problems, Alford & Head (2017) applied similar dimensions, where problem complexity related to problem/solution clarity and stakeholder difficulty considered the cooperation level connected to knowledge, interest and power. Jonassen (2004) broadens these views, proffering that problems vary in at least four dimensions: structuredness, complexity, dynamicity and domain specificity (or abstractness). Olewnik et al. (2020) added to this work with dimensions to address problem-solving in engineering education, specifically: complexity and structuredness, familiarity, structural knowledge, metacognition, epistemological commitments, and attention to affective domains. SoS problems were characterised using 3 dimensions based on structure and behaviour – system type, degree of control and connectivity (DeLaurentis & Crossley, 2005).

While problem typologies had more variability that other themes, common areas across multiple references were complexity, dynamicity, stakeholder nature, structuredness and domain. Understanding and monitoring changes in the problem space is crucial in the development of solutions for evolving and emergent SoS.

Capability Theme

Defence organisations across the globe have employed capability frameworks over many years to ensure the development, delivery and management of a holistic, functional capability that encompasses all non-materiel aspects. They have evolved as knowledge has grown and have been tailored to drive national priorities. The United States applies the DOTmLPF-P typology as part of its Joint Capabilities Integration and Development System, JCIDS (Rhyne, 2014; USDoD, 2021). NATO and Norway have modified this typology to include interoperability (DOTMLPF-I) and information systems and economy (DOTMLPF-IE). The Defence Lines of Development (DLODs), known by the acronym TEPIDOIL, are used for capability acquisition in the United Kingdom's Ministry of Defence (Fisher, 2024); recently adding interoperability as a dimension. The current Canadian capability framework is very structured and decomposed; it is known as PRICIE + G, where generate (G) was the progression (Pagotto & Walker, 2004; Pelletier, 2016). The Fundamental Inputs to Capability (FIC) are the Australian capability framework (ADoD, 2011; ADoD, 2022; ADoD, 2025) and have adapted over time to include 10 dimensions, that are not as neatly packaged or *acronym-ised* as those above.

Non-defence organisations also "utilise typologies to understand systems operation as a holistic capability. The complex systems domain identified issues in categories of human/social, information, organisational/managerial, policy/political and technological/technical (Keating et al. 2015). Six system categories affecting digital transformation were recognised as physical/infrastructure, cognitive, social, digital, business and policy systems, plus the whole system (Papavasiliou et al. 2020). The socio-political framework, ASCOPE, is often used in conjunction with strategic environmental typologies (UKMoD, 2016). Categories of systems within an SoS were specified as resources, stakeholders, operations, policies (DeLaurentis & Crossley, 2005). Similarly, SoS entities were categorised as stakeholders, information, resources, operations, and infrastructure (Fan & Mostafavi, 2020).

Similarities and differences were easily observed across these, with Table 3 providing the most aligned dimensions for comparison. Most considered the need for a holistic and/or interaction category (even if not specified as a dimension). Isolated ideas (those in 1-2 typologies) included industry, research & development, policy, and economy. The common 9 dimensions were identified and labelled to form the acronym SOPHISTIC: System-of-Systems; Organisational; Physical Equipment; Human-related aspects; Infrastructure; Support; Training and education; Information; Concepts and doctrine.

Context Theme

The context exerts significant influence on the system of interest, its problems, evolution, potential solutions and the engineering methodologies applied. Rittel & Webber state that "one cannot understand the problem without knowing about its context" and orienting its solution (1978:162). Within defence, the context and environment are significant shaping elements, both in operations and day-to-day business. Sadly, context and environment are both overloaded terms. Systems Engineering (SE) defines context as the "immediate environment in which a function (or set of functions in a diagram) operates" ISO/IEC/IEEE 24765 (2017:96). While environment, is defined as the surroundings and/or conditions that impact on, and are impacted by, an organism or object (OED online, 2025). Three distinct foci for context typologies were identified within the literature review – strategic or macro-environment, physical/non-physical environment, and domain.

Numerous typologies are used to understand macro-environmental factors in business and social disciplines. The PEST framework (Aguilar, 1967) has been adapted to many variants with dimensions including Political, Economic, Social, Technological, environmental/ecological, legal, ethical, international, industry and demographic categories (Johnson et al. 2017). In business analysis, the CAGE framework measures compatibility across four areas: Cultural, Administrative & political, Geographic and Economic. The defence sector use DIME-FIL (Diplomatic, Information, Military, Economic, Financial, Intelligence, Law enforcement) and PMESII-PT (Political, Military, Economic, Social, Infrastructure, Information, Physical environment, Time) to appreciate the impacts of strategic factors on operations (Hartley, 2017; OJCS, 2011; UKMoD, 2016). Dimensions correlated in multiple typologies were political, economic, social, technological, environmental, legal-ethical and military. Different macro-environmental factors will influence the SoS at different degrees throughout the lifecycle; understanding of the appropriate factors and their implications significantly affects SoSE success.

AS: FIC [1,2,3]	CA: PRICIE+G [4,5]	UK: DLODs [6]	US: DOTMLPF-P [7,8]	NATO/Norway: DOTMLPF-I/IE [9]	Non-Defence [10,11,12,13,14]

Command & Management (Concepts & Doctrine) [1]	Concepts & Doctrine [4]	Doctrine & Concepts [6]	Doctrine [7,8]	Doctrine [9]	Managerial [10] Operations [12,13]
Collective Training [1]	Generate [4,5]	Training [6]	Training [7,8]	Training [9]	
Command & Management (Indiv. Training/Leadership) [1]	Leadership & Personnel [4]		Leadership & Education [7,8]	Leadership & Education [9]	Managerial [10]
Personnel [1]		Personnel [6]	Personnel [7,8]	Personnel [9]	Human/Social [10] Cognitive/Social [11] Stakeholders [12,13] People [14]
Organisation [1]	Organisation	Organisation [6]	Organisation [7,8]	Organisation [9]	Organisational [10] Organisations [14]
Facilities & Training Areas [1]	Infrastructure	Infrastructure [6]	Facilities [7,8]	Facilities [9]	Infrastructure [11,13] Structures [14]
	& Environment [4]				Areas [14]
Major Systems [1]	Equipment	Equipment [6]	Materiel [7,8]	Materiel [9]	Technological/ Technical[10] Capabilities [14]
Support [1]	& Support [4]	Logistics [6]			Resources [12,13]
Supplies [1]					
Data [1,3]	Information Management & Technology [4]	Information [6]		Information systems [9]	Information [10,13] Digital [11]
		Interoperability [6]		Interoperability [9]	

Reference Key: [1] ADOD (2025); [2] ADoD (2016);[3] ADoD (2024); [4] Pagotto & Walker (2004); [5] Pelletier (2016); [6] Fisher (2024); [7] Rhyne (2014); [8] USDoD (2021); [9] “DOTMLPF” (2025); [10] Keating et al. (2015); [11] Papavasiliou et al. (2020); [12] DeLaurentis & Crossley (2005); [13] Fan & Mostafavi (2020); [14] UKMoD (2016)

Table 3. Comparison of Capability Typologies.

The natural environment is often addressed as a separate dimension within typologies. Earth science utilises the 4 spheres of the natural environment, while geography splits into physical and human (where physical geography sub-disciplines align to the spheres). Human geography covers social, cultural, behavioural, urban, economic and political aspects. Similar dimensions are used in the Global Ecosystem Typology (Keith et al. 2020). The physical environment also includes human-made elements such as buildings, communications, transportation and infrastructure elements. Within defence, various typologies focus on the influence of natural, human-made and human environments on engineering and operations (USDoD, 2021; ADoD, 2024; ADoD, 2021). Additionally, the military environment or characteristics of military actors (own force, ally, threat and neutral) are used in analysis including the capabilities, mission/intent and doctrine. This suite of environmental aspects has a substantial impact on prospective solutions, and varies depending on the problem type, SoS type/scope and lifecycle phase. Awareness of the environment and discerning changes that affect the SoS and its engineering can be guided using a suitable typology.

Domain is often raised within typologies, as a dimension or in their adaptation to suit a particular area of interest/application. Domain is another overloaded term, with the SE Vocabulary providing 3 definitional statements: a problem space, area of knowledge or activity, and a distinct scope (ISO/IEC/IEEE 24765 2017:145). Hence, typologies in this theme may be focused on disciplines, sectors, applications, scale or combinations of these. SE application domains encompass aerospace, automotive, business, consumer products, disaster response, defence, energy, finance, healthcare, information & communications technology, infrastructure & construction, manufacturing, media, natural environment & resource management, space, telecommunications and transportation (Barot et al. 2012a, 2012b; Bendov et al. 2012; Cook et al. 2012; Dahmann & DeLaurentis, 2023; INCOSE, 2015; Nielsen et al. 2015; Sage & Lynch, 1998). Industrial sectors (government, civil, military and commercial) may also be referred to as domains. Even academic disciplines and sub-disciplines can be designated as domains (ABS, 2020). In a military sense, domain is the "physical or non-physical medium of discrete characteristics in the operational environment within, and through which, military action occurs" (ADoD, 2021:128). Common defence domains are land, maritime, air, cyber and space, with operations occurring within and across multiple or all domains concurrently. While there are many perspectives, each domain has its own concepts, issues, policies, laws, standards, and therefore own knowledge and wisdom base. Thus, domain insight improves tailoring of engineering methodology and process, leading to increased success in delivery.

Governance Theme

Management and governance are key spheres of influence for SoS and naturally, a variety of typologies have been developed to support this area, typically applying a functional or holistic perspective. Gorod et al. (2009), using a functional view of SoSE management, suggest five categories for action: risk, configuration, performance, policy and resource management. Four styles of management aligned to four organisational types were proposed to support increased flexibility for SoS (Mansouri et al. 2009). Based on US Navy practice of 8 essential elements of good governance, a criteria-based framework was recommended for development of a governance strategy (Vaneman & Jaskot, 2013). Keating et al. (2015) developed a metasystem approach to complex systems governance using 9 metasystem functions (known as the metasystem) and 3 other interconnected elements (environment, context and system).

Analysis Summary

The literature review confirmed that typologies are developed to target a specific application and often area of interest. Some group categories or dimensions to simplify analysis or understanding, or due to natural correlations. For example, SoS type, while focused on management control or governance, draws in elements of operational interaction and purpose alignment. Typologies also evolve to meet specific needs and may lose rigour and clarity in this process. Commonality in dimensions and categories was found within and across themes.

A qualitative analysis of over 140 collected typologies included coding against defined purposes and the use of grounded theory leading to 17 typology and 23 category types. Clustering analysis of types and assessment of category relevance to SoSE provided additional insights. Over half the typologies were used to *understand* or *classify*; however, the rationale for capability and governance typologies was typically to *guide*. The main typology types were systems, complexity and SoS, followed by context and capability. The largest typology contained 17 categories, and the median number of categories was 5. The most used category codes were capability, domain-type, system, complexity, method-concept, environment, governance, time-evolution, context and sociological. Over 40% of the 780 individual categories were deemed to provide significant insight to SoSE and 16% rated as limited or nil relevance. Category types awarded a significant median rating were capability, complexity, context, domain-type, interactions, mission-purpose, outcome-operation, problem, scope-span, size, sociological, stakeholder and time-evolution. This analysis of typologies has provided a comprehensive understanding and highlighted areas of significant impact for SoSE for inclusion in a typology.

The SoSE Typology

An SoSE typology based on a structure of axes, dimensions and categories has been developed through a multidisciplinary literature review and extensive qualitative analysis. The typology consists of five primary axes – Complexity, Context, Capability, SoS focus and Management focus – each comprising multiple dimensions to reflect the scope and relationships within SoSE. An illustration of the axes and their dimensions highlighting the interdependencies and relationships is shown in Figure 1. Complexity, a fundamental component, is placed at the heart of the diagram, while context provides the circumstances within which all axes exist. Capability, SoS and Management focus axes concentrate on the problems and their capability solutions and are highly interdependent and interactive.

Dimensions capture the salient aspects of each axis, while their subordinate categories provide detailed understanding and coverage. Further granularity is possible by breakdown into subcomponents if required. Assessments may be made using summary or Likert-style scales, depending on user needs and data availability, to compare or share the understanding or status of each area. An overview description of each axis is provided below, while Table 4 presents a summary of the identified axes, dimensions, categories and potential for summary scale use.

A key component of the typology is the **Complexity** axis. It was identified as an impacting factor for most dimensions, which is why it is positioned centrally and overlaps the other axes. Four key dimensions were identified during the literature review analysis: size, connectivity, dynamicity and diversity. Complexity does not arise from high levels in one dimension alone; but emerges from the interplay and combination of dimensions (Firesmith, 2010; Sheard & Mostashari, 2011).

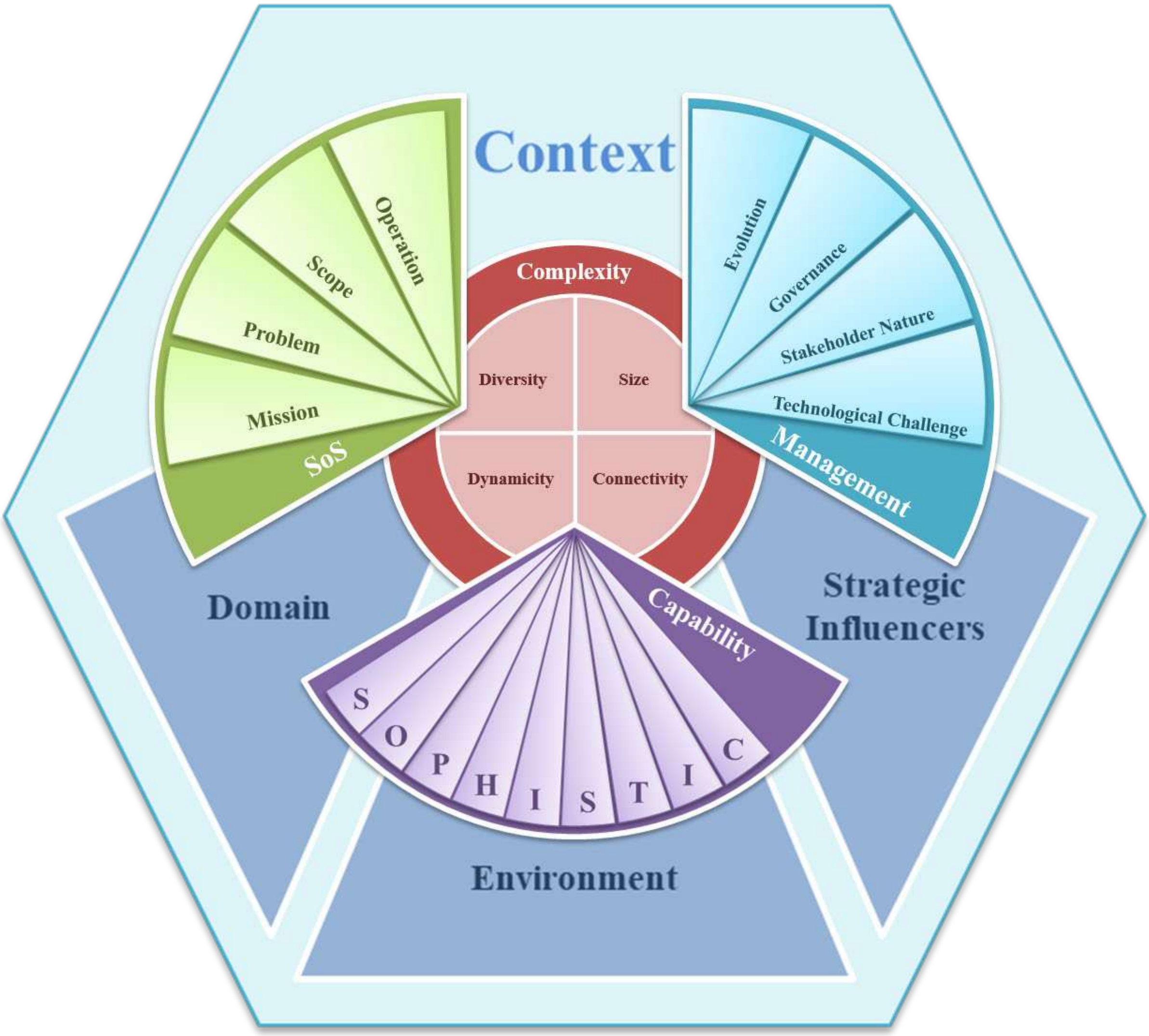

Figure 1. The SoSE Typology

Context situates our understanding of the system of interest, its problems and potential solutions, which for SoS can be extremely broad in scope and scale, evolving and interacting with other systems generating unexpected emergence. It is separated into 3 dimensions: domain, environment and strategic influencers. Reflection of the influence of complexity on these dimensions and their categories will improve understanding and awareness of the impacts of evolution. This axis and its dimensions/ categories are not easily aggregated or assessed as their influence is typically subjective.

Axis	Dimension	Summary scale	Categories
Complexity		Likert level	
	Connectivity	Likert level	interaction type & number, interdependence, coupling
	Diversity	Likert level	heterogeneity/variability, configurations
	Dynamicity	Likert level	evolution rate, volatility
	Size	Likert level	number of systems, sub-systems & elements
Context		N/A	
	Domain	N/A	* chosen to suit SoS/problem
	Environment	N/A	natural physical, human-made physical, non-physical, military
	Strategic influencers	N/A	political, economic, sociological, technological, environmental, legal/ethical
Capability		N/A	
	SoS	N/A	holistic perspective and overlaps including integration & interoperability
	Organisational	N/A	structural aspects (management, control, task teaming & formations)
	Physical equipment	N/A	physical materiel & technology
	Human-related	N/A	personnel, leadership, sociological, culture, psycho-social conditions, human factors
	Infrastructure	N/A	buildings, facilities, areas
	Support	N/A	supplies, engineering, movement, maintenance
	Training & education	N/A	individual training, collective training, education, qualifications, lessons learned
	Information	N/A	data, information, processing, transfer, knowledge management
	Concepts & doctrine	N/A	philosophy, concepts, doctrine, tactics, techniques, procedures/processes
SoS Focus		N/A	
	Mission	Likert type	mission clarity, stability, alignment
	Problem	Likert type	structuredness, (complexity)
	Scope	Likert level	number of elements, geographic distribution, size, span of influence
	Operation	Likert type	employment, functionality, requirements
Management Focus		N/A	
	Evolution	Likert level	lifecycle stage, type, adaptability
	Governance	SoS type	authority, ownership, management, resource allocation
	Stakeholder nature	Likert type	relationships, agreement, involvement
	Technological challenge	Likert type	technical engineering level, range of innovation, novelty (greenfield - brownfield)

Table 4. Key SoSE areas from clustering analysis

The **Capability** axis focuses on ensuring the materiel and non-materiel aspects associated with development, acquisition and management are incorporated. Nine dimensions and their relevant categories were generated through the analysis of the reviewed typologies and are represented through the acronym SOPHISTIC. Categories may be extended or further decomposed as necessary for the situation. As with context, contemplation of complexity dimension effects is important for these dimensions, and their evaluation is not well suited to simple scales.

The typological components of the SoS of interest itself are captured in the **SoS focus** axis and its 4 dimensions of mission (or purpose), problem, scope and operation (or outcome). These dimensions are forcing functions for the engineering and must be monitored continually due to their expected evolution and the effect of emergence. Complexity within the SoS is integral to understanding each of these dimensions, so the impacts of size, connectivity, dynamicity and diversity should be fully considered and may be more easily evaluated in the categories contained therein. The generation of Likert-style types to label sub-categories that are matched to the domain of application can assist in the development and maintenance of common understanding with stakeholders and engineering teams.

The **Management focus** axis clusters the engineering aspects related to development, delivery and management of the SoS. Four dimensions of management were recognised as evolution, governance, stakeholder nature and technological challenge. As with SoS focus, these are strongly affected by complexity so the influence of complexity dimensions should be addressed in the analysis of this axis. Similarly, the use of known or developed labels for categories can support shared awareness amongst teams. Such domain-appropriate labels could include ISO/IEC/IEEE 15288 lifecycle terminology or SoS type (ISO/IEC/IEEE 21841:2019).

Using The Typology

The SoSE typology serves as continuous reference for the SoSE and management teams to comprehensively understand the SoS and its engineering context throughout the lifecycle. It defines key axes and dimensions, enabling the user to decompose and elucidate further as needed. The literature review highlighted numerous alternate categories and options for refinement. The SoSE typology should be reviewed deeply initially and tailored to the specific situation and system of interest to ensure careful selection of axes, dimensions and level of detail. Regular review of such customisation is essential due to the dynamic nature of SoSE.

Typology users should systematically address each axis and dimension as chosen, describing the rationale, supporting data and rating schema(s) chosen for the resultant assessment. The justification for exclusion of areas within the typology should be captured. Once knowledge and understanding have been gathered across all axes, a holistic reflection of the SoSE enterprise should occur, including consideration of interactions and interdependencies between axes and dimensions. Key areas of risk and opportunity, knowledge gaps, and issues for resolution should be flagged and monitored. All collected typology information must be carefully stored and managed as a key resource for other SoSE actions.

Conclusion

A multidisciplinary literature search identified over 200 references and extracted 140 typologies of SoS relevance for detailed review. However, there was no single comprehensive typology identified to support SoSE directly. The discovered typologies were analysed using thematic and grounded theory techniques to ascertain key themes, common areas of impact and categories of SoS relevance. Insights gained through this analysis enabled the design of a five axis multi-dimensional typology for SoSE. This typology was built to fulfil the design criteria of practicality, coverage, simplicity and flexibility, which were met by using:

- structure and inter-relationships (internal homogeneity / external heterogeneity)
- parsimony (limitation of dimensions/categories to the Miller number)
- systematic and transparent construction method and alignment to literature

- options for categories and assessment methods
- clear and meaningful descriptions

The SoSE Typology provides experts with a structured support tool and inexperienced users with schemas to understand the SoSE space: the SoS, its constituent systems (CS), context, problem and solution development. It increases their ability to recognise problems, options and risks and empowers decision making. The application of this typology is an essential component of any SoSE process.

Acknowledgements

This paper summarises a thesis chapter submission as part of a PhD in Systems Engineering at The University of Adelaide. The author also wishes to acknowledge the support of the Defence Science and Technology Group in this undertaking.

References

ADoD. (2022). *Defence Capability Manual*. Version 1.2. Canberra, ACT: Defence Publishing

ADoD. (2025). *The One Defence Capability System (ODCS) Manual*. Version 2. Canberra, ACT: Defence Publishing.

Aguilar, F. J. (1967) *Scanning the Business Environment*. New York: Macmillan.

Alford, J., & Head, B. W. (2017). Wicked and less wicked problems: a typology and a contingency framework. *Policy and Society*, 36(3), 397-413. doi:10.1080/14494035.2017.1361634

Australian Bureau of Statistics (ABS). (2020). *Australian and New Zealand Standard Research Classification (ANZSRC)*. Retrieved from https://www.abs.gov.au/statistics/classifications/australian-and-new-zealand-standard-research-classification-anzsrc/latest-release.

Australian Department of Defence (ADoD). (2011). *The Defence Capability Development Handbook Interim*. Canberra, ACT

Australian Department of Defence. (2021). *Planning*. (ADF-P-5 Planning Doctrine). Canberra, ACT.

Australian Department of Defence. (2024). *Decision-Making and Planning Processes*. (ADF-I-5). Canberra, ACT: Doctrine Directorate

Babbie, E. R. (2007). *The Practice of Social Research* (11th ed.). Belmont, CA.: Thomson Wadsworth.

Bakhshi, J., Ireland, V., & Gorod, A. (2016). Clarifying the project complexity construct: Past, present and future. *International Journal of Project Management*, 34(7), 1199-1213. doi:10.1016/j.ijproman.2016.06.002

Barot, V., Dogan, H., Henshaw, M., Sinclair, M., Siemieniuch, C., & Henson, S. (2012a). *The SoSE Thesaurus Approach* (TAREA-PU-WP4-R-LU-14).

Barot, V., Henson, S., Henshaw, M., Siemieniuch, C., Sinclair, M., Lim, S. L., ... DeLaurentis, D. (2012b). *SoA Report: State of the Art on Systems of Systems Management and Engineering* (TAREA-PU-WP2-D-LU-9).

Beer, S (1972). *Brain of the Firm: The managerial cybernetics of organization*, London: Allen Lane, The Penguin Press.

Bendov, N., Winokur, M., Lochow, T., Sanduka, I., Honour, E., Paul, S., ... Kalawsky, R. S. (2012). *Characterization of SoS*. 7th Framework Programme.

Boardman, J., & Sauser, B. (2006, 24-26 April 2006). *System of Systems – the meaning of 'of'*. Paper presented at the IEEE/SMC International Conference on System of Systems Engineering, Los Angeles, CA, USA.

Boulding, K. E. (1956). General systems theory-the skeleton of science. *Management science*, 2(3), 197-208. doi:10.1287/mnsc.2.3.197

Calvano, C. N., & John, P. (2004). Systems engineering in an age of complexity. *Systems Engineering*, 7(1), 25-34. doi:10.1002/sys.10054

Collier, D., LaPorte, J., & Seawright, J. (2012). Putting Typologies to Work: Concept Formation, Measurement, and Analytic Rigor. *Political Research Quarterly*, 65(1), 217-232. doi:10.1177/1065912912437162

Cook, S. C., & Pratt, J. M. (2016). *Typology dimensions for classifying SoSE problem spaces*. Paper presented at the 11th System of

Systems Engineering Conference (SoSE), Kongsberg, Norway.
Cook, S. C., Lawson, E., & Allison, J. S. (1999). Towards a Unified Systems Methodology for Australian Defence Systems-of-Systems. *INCOSE Annual Symposium*, 9(1), 13-21. doi:10.1002/j.2334-5837.1999.tb00137.x
Dahmann, J. S., & DeLaurentis, D. (2023). Unique challenges in system of systems analysis, architecting, and engineering. In D. Verma (Ed.), *Systems Engineering for the Digital Age: Practitioner Perspectives* (pp. 583-600): John Wiley & Sons, Inc.
DeLaurentis, D. A., & Crossley, W. A. (2005). *A taxonomy-based perspective for systems of systems design methods*. Paper presented at the Systems, Man and Cybernetics, 2005 IEEE International Conference on, Waikoloa, HI. doi:10.1109/ICSMC.2005.1571126.
Dori, D., Sillitto, H., Griego, R. M., McKinney, D., Arnold, E. P., Godfrey, P., ... Krob, D. (2020). System Definition, System Worldviews, and Systemness Characteristics. *IEEE Systems Journal*, 14(2), 1538-1548. doi:10.1109/JSYST.2019.2904116
DOTMLPF. (2025, 21 August). In *Wikipedia*. https://en.wikipedia.org/wiki/DOTMLPF.
Doty, D. H., & Glick, W. H. (1994). Typologies as a Unique Form of Theory Building: Toward Improved Understanding and Modeling. *The Academy of Management Review*, 19(2), 230-251. doi:10.2307/258704
Fan, C., & Mostafavi, A. (2020). Metanetwork Framework for Performance Analysis of Disaster Management System-of-Systems. *IEEE Systems Journal*, 14(1), 1265-1276. doi:10.1109/JSYST.2019.2926375
Firesmith, D. (2010). *Profiling Systems Using the Defining Characteristics of Systems of Systems (SoS)*. Carnegie Mellon University, Software Engineering Institute, Report CMU/SEI-2010-TN-001.
Fisher, R. (2024). Comparing Historic Military Capabilities. *The RUSI Journal*, 169(1-2), 76-90. doi:10.1080/03071847.2024.2347298
Flood, R. L., & Jackson, M. C. (1991). *Creative problem solving: Total systems intervention* (Vol. 55): Wiley Chichester.
Gideon, J. M., Dagli, C. H., & Miller, A. (2005). *Taxonomy of systems-of-systems*. Paper presented at the Conference on Systems Engineering Research, Hoboken, NJ.
Gorod, A., DiMario, M., Sauser, B., & Boardman, J. (2009). 'Satisficing' system of systems using dynamic and static doctrines. *International Journal of System of Systems Engineering*, 1(3), 347-366. doi:10.1504/ijsse.2009.029909
Gorod, A., Sauser, B., & Boardman, J. (2008). System-of-Systems Engineering Management: A Review of Modern History and a Path Forward. *IEEE Systems Journal*, 2(4), 484-499. doi:10.1109/jsyst.2008.2007163
Hallo, L., & Gorod, A. (2019). Toward 'satisficing' creativity effort within System of Systems Engineering (SoSE) management. *Australian Journal of Multi-Disciplinary Engineering*, 15(1), 34-43. doi:10.1080/14488388.2019.1661812
Hartley, D. S. (2017). The DIME/PMESII Paradigm. In D. S. Hartley Iii (Ed.), *Unconventional Conflict: A Modeling Perspective* (pp. 99-106). Cham: Springer International Publishing.
Helmsman Institute, T. (2012). *A Comparison of Project Complexity between Defence and other Sectors*. Retrieved from www.helmsman-institute.com.
Henrie, M., & Delaney, E. E. (2005). *Towards a common system of systems vocabulary*. Paper presented at the 2005 IEEE International Conference on Systems, Man and Cybernetics, Waikoloa, HI. doi:10.1109/ICSMC.2005.1571563.
Hitchins, D. K. (2007). *Systems Engineering: A 21st Century Systems Methodology*. Hoboken, NJ, USA: John Wiley and Sons.
INCOSE. (2015). *INCOSE Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities* (4th Edition ed.): John Wiley & Sons.
ISO/IEC/IEEE. (2017). (context) (domain) International Standard - Systems and software engineering --Vocabulary. In *ISO/IEC/IEEE 24765:2017(E)* (pp. 1-541). doi:10.1109/IEEESTD.2017.8016712
ISO/IEC/IEEE. (2019). Systems and software engineering -- Guidelines for the utilization of

ISO/IEC/IEEE 15288 in the context of system of systems (SoS). In *ISO/IEC/IEEE 21840:2019(E)* (pp. 1-68).
ISO/IEC/IEEE. (2019). Systems and software engineering -- Taxonomy of systems of systems (International Standard). In *ISO/IEC/IEEE 21841:2019(E)* (pp. 1-20).
ISO/IEC/IEEE. (2023). Systems and software engineering--System life cycle processes. In *ISO/IEC/IEEE 15288:2023(E)* (pp. 1-128).
Jackson, M. C., & Keys, P. (1984). Towards a system of systems methodologies. *Journal of the operational research society*, 35, 473-486. doi:10.1057/jors.1984.101
Johnson, G., Whittington, R., Scholes, K., Angwin, D., & Regnér, P. (2017). *Exploring Strategy* (11th ed.): Pearson Education.
Jonassen, D. H. (2004). *Learning to solve problems: An instructional design guide* (Vol. 6): John Wiley & Sons.
Jordan, N. (2003). Some thinking about 'system'. In *Themes in Speculative Psychology*: Taylor & Francis Group.
Kanger, L. (2024). When the types do not make sense: Seven lessons to improve typology-building for energy transitions research. *Energy Research & Social Science*, 107, 103360. doi:10.1016/j.erss.2023.103360
Kaplan, A. (1964). *The Conduct of Inquiry*. San Francisco, CA: Chandler.
Karcanias, N., & Hessami, A. G. (2010). *Complexity and the notion of system of systems: part (I): general systems and complexity*. Paper presented at the World Automation Congress (WAC), 2010, Kobe, Japan.
Kazman, R., Schmid, K., Nielsen, C. B., & Klein, J. (2013, 2-6 June 2013). *Understanding patterns for system of systems integration*. Paper presented at the 2013 8th International Conference on System of Systems Engineering (SoSE), Maui, HI. doi:10.1109/SYSoSE.2013.6575257.
Keating, C. B., & Katina, P. F. (2012). Prevalence of pathologies in systems of systems. *International Journal of System of Systems Engineering*, 3(3), 243-267. doi:10.1504/IJSSE.2012.052688
Keating, C. B., Kaufmann, P., & Dryer, D. (2001). A framework for systemic analysis of complex issues. *The Journal of Management Development*, 20(9), 772-784. doi:10.1108/02621710110405479
Keating, C., Katina, P., & Bradley, J. (2015). *Challenges for Developing Complex System Governance*. Paper presented at the 65th Annual Conference & Expo of the Institute of Industrial Engineers, Nashville, Tennessee.
Keith, D. A., Ferrer-Paris, J. R., Nicholson, E., & Kingsford, R. (2020). *IUCN Global Ecosystem Typology 2.0: descriptive profiles for biomes and ecosystem functional groups*. Gland, Switzerland: IUCN.
Kemp, D., Camm, D., Evans, R., & Elphick, J. (2013). Steampunk System of Systems Engineering: A case study of successful System of Systems engineering in 19th century Britain. *INCOSE International Symposium*, 23(1), 617-633. doi:10.1002/j.2334-5837.2013.tb03043.x
Kinder, A., Barot, V., Henshaw, M., & Siemieniuch, C. (2012). *System of Systems: Defining the system of interest*. Paper presented at the 7th IEEE International Conference on System of Systems Engineering, Piscataway, NJ, USA. doi:10.1109/SYSoSE.2012.6384211.
Kluge, S. (2000). Empirically Grounded Construction of Types and Typologies in Qualitative Social Research. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, 1(1). doi:10.17169/fqs-1.1.1124
Kovacic, S., Sousa-Poza, A., & Keating, C. (2008, 2-4 June 2008). *Complex situations: An alternative approach for viewing a System of Systems*. Paper presented at the 2008 IEEE International Conference on System of Systems Engineering (SoSE). Monterey, CA.
Kurtz, C. F., & Snowden, D. J. (2003). The new dynamics of strategy: Sense-making in a complex and complicated world. *IBM systems journal*, 42(3), 462-483. doi:10.1002/j.2334-5837.2013.tb03043.x.
Lewis, G., Morris, E., Place, P., Simanta, S., Smith, D., & Wrage, L. (2008). *Engineering systems of systems*. Paper presented at the 2008 2nd Annual IEEE Systems Conference.

Maier, M. W. (1998). Architecting Principles for Systems-of-Systems. *Systems Engineering*, 1(4), 267-284. doi:10.1002/(SICI)1520-6858(1998)1:43.0.CO;2-D

Mansouri, M., Gorod, A., & Sauser, B. (2010). *A typology-based approach to adopting effective management styles for enterprise systems*. Paper presented at the 2010 IEEE International Systems Conference, San Diego, CA, USA.

Mansouri, M., Gorod, A., Wakeman, T. H., & Sauser, B. (2009, May 30 -June 3). *A systems approach to governance in Maritime Transportation System of Systems*. Paper presented at the IEEE International Conference on System of Systems Engineering (SoSE), 2009.

Moses, J. (2004). *Foundational Issues in Engineering Systems: A Framing Paper*. Engineering Systems Monograph. March 29-31, 2004. Retrieved from MIT.

Mostafavi, A., Abraham, D. M., DeLaurentis, D., & Sinfield, J. (2011). Exploring the Dimensions of Systems of Innovation Analysis: A System of Systems Framework. *IEEE Systems Journal*, 5(2), 256-265. doi:10.1109/JSYST.2011.2131050

Nielsen, C. B., Larsen, P. G., Fitzgerald, J., Woodcock, J., & Peleska, J. (2015). Systems of Systems Engineering: Basic Concepts, Model-Based Techniques, and Research Directions. *ACM Computing Surveys (CSUR)*, 48(2), 1-41. doi:10.1145/2794381

OED (Oxford English Dictionary) (2025) *environment* sense 2.b/2.c, March 2025, doi:10.1093/OED/1071741346 / doi:10.1093/OED/9744056549

Office of the Joint Chiefs of Staff (OJCS). (2011). *Commander's Handbook for Assessment Planning and Execution*. Joint and Coalition Warfighting. Suffolk, VA

Olewnik, A., Yerrick, R., Simmons, A., Lee, Y., & Stuhlmiller, B. (2020). Defining Open-Ended Problem Solving Through Problem Typology Framework. *International Journal of Engineering Pedagogy (iJEP)*, 10(1), pp. 7-30. doi:10.3991/ijep.v10i1.11033

Pagotto, J., & Walker, R. S. (2004). *Capability engineering - Transforming defence acquisition in Canada*. Paper presented at the Battlespace Digitization and Network-Centric Systems IV, April 13, 2004 - April 15, 2004, Orlando, FL, United states.

Papavasiliou, S., Gorod, A., & Reaiche, C. (2020, 2-4 June 2020). *A System of Systems Management Framework for Digital Transformation in eGovernment*. Paper presented at the 2020 IEEE 15th International Conference of System of Systems Engineering (SoSE).

Partelow, S. (2023). What is a framework? Understanding their purpose, value, development and use. *Journal of Environmental Studies and Sciences*, 13(3), 510-519. doi:10.1007/s13412-023-00833-w

Pelletier, E. (2016). *Operational research and analysis supporting Canadian Army PRICIE + G analyses: A planning and collaboration tool*. (DRDC-RDDC-2016-R200).

Potts, M. W., Johnson, A., & Bullock, S. (2020). Evaluating the complexity of engineered systems: A framework informed by a user case study. *Systems Engineering*, 23(6), 707-723. doi:10.1002/sys.21558

Rhyne, D. W. (2014). *US-Coalition Forces and Host Nations: DOTmLPF-P for Contingency Procurements*. Part 2. Conclusion. Retrieved from DTIC.

Rittel, H. W., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy sciences*, 4(2), 155-169. doi:10.1007/BF01405730

Sage, A. P., & Lynch, C. L. (1998). Systems integration and architecting: An overview of principles, practices, and perspectives. *Systems Engineering*, 1(3), 176-227. doi:10.1002/(sici)1520-6858(1998)1:3<176::Aid-sys3>3.0.Co;2-l

Senge, P. M. (1990). *The Fifth Discipline: The Art & Practice of The Learning Organization* (1st ed.). New York: Doubleday/Currency.

Sheard, S. A., & Mostashari, A. (2011). Complexity Types: From Science to Systems Engineering. *INCOSE International Symposium*, 21(1), 673-682. doi:10.1002/j.2334-5837.2011.tb01235.x

Sheard, S. A., et al. (2021). *A Complexity Primer for Systems Engineers Revision 1*. INCOSE Complex Systems Working Group White Paper.

Sillitto, H. G. (2009). On Systems Architects and Systems Architecting: some thoughts on explaining and improving the art and science of systems architecting. *INCOSE International Symposium*, 19(1), 970-985. doi:10.1002/j.2334-5837.2009.tb00995.x

Smith, J. A., Harikumar, J., & Ruth, B. G. (2010). *Another Perspective on System of Systems: A Step Towards an Analytical Framework*. Paper presented at the 2010 4th Annual IEEE Systems Conference, 5-8 April 2010, Piscataway, NJ, USA.

Smith, K. B. (2002). Typologies, Taxonomies, and the Benefits of Policy Classification. *Policy Studies Journal*, 30(3), 379-395. doi:10.1111/j.1541-0072.2002.tb02153.x

Stevens, R. (2008). *Profiling Complex Systems*. Paper presented at the 2008 2nd Annual IEEE Systems Conference, Montreal, QC, Canada.

Tekinerdogan, B. (2019). *Multi-Dimensional Classification of System-of-Systems*. Paper presented at the 14th Annual System of Systems Engineering Conference, Anchorage, Alaska, USA.

UKMoD (2016). *Understanding and Decision-making. Joint Doctrine Publication 04 (JDP04)* (2nd ed.). Swindon, Wiltshire, UK: Development, Concepts and Doctrine Centre (DCDC)

United States Department of Defense (USDoD). (2021, 31 October). *Manual for the Operation of the Joint Capabilities Integration and Development System (JCIDS)*, Joint Chiefs of Staff J-8.

Vaneman, W. K., & Jaskot, R. D. (2013, 15-18 April 2013). *A criteria-based framework for establishing system of systems governance*. Paper presented at the 2013 IEEE International Systems Conference (SysCon).

Weaver, W. (1948). Science and Complexity. *American Scientist*, 36(4), 536-544. Retrieved from http://www.jstor.org/stable/27826254.

Biography

Jaci Pratt

is a System-of-Systems Engineering and Integration researcher at the Defence Science and Technology (DST) Group in the Australian Department of Defence. She has worked in DST Group for over 30 years in areas as diverse as Modelling, Simulation, RF Stimulation, Experimentation, Systems Analysis, Information Systems and Test & Evaluation supporting Land, Air, Maritime and Intelligence domains. Jaci holds a BSc (Hons) from Flinders University and is completing a PhD in System-of-Systems Engineering with the University of Adelaide.