Investigating Systems Engineering Competencies in Norwegian Defense Industry to Strengthen the Role Definition

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Abstract

This study investigates the roles and competencies of systems engineers within a large Norwegian defense contractor to understand what factors contribute to the challenges in defining the systems engineering role and provide input that can strengthen the role definition in the company. The defense industry has experienced rapid growth in recent years, with increasing systems complexity. While working to overcome these challenges, even more importance will be put on systems engineers, as they facilitate successful system realization.

The investigation provides insights into roles and competencies in the Norwegian defense industry and compares these findings with a similar study conducted within high-tech industries in the Netherlands. This comparison reveals similarities between the two countries. Furthermore, this study suggests that factors such as rapid growth, a young workforce, a broad variety of role titles, and organizational restructuring contribute to the difficulty in defining the role. To provide input in strengthening the role definition, this study compares current competency levels with the knowledge areas of the π-shaped model. It proposes developing a collective understanding of systems engineering to strengthen role definition and enhance competencies in areas such as life cycles and finance.

Keywords

Systems Engineering Competencies, Systems Engineering Competency Framework, Systems Engineering Skills, Competency Definition.

Introduction

Research Background

As the geopolitical situation becomes increasingly unstable, the Norwegian Government proposes to increase the defense budget to align with NATOs target of 5% of gross domestic product (GDP) on defense and security, whereas minimum 3,5% is devoted to core defense capabilities (Norwegian Government, 2026). In addition to strengthening the defense capabilities, the Norwegian Government has earmarked almost 1 billion NOK for the defense industry to ensure increased production capacity and technological advancements to support security needs (Norwegian Government, 2024). Norway has been providing substantial support to Ukraine in response to the ongoing war. In 2026, this support is estimated to amount a total of 85 billion NOK. 70 billion NOK for military support and 15 billion NOK as civilian support (Norwegian Government, 2026).

These investments reflect the need for advanced military equipment, which the Norwegian defense industry will be a contributor to for years. INCOSE (2021) states that with increasing demand, market competition, and system complexity, systems engineering practices will continue to evolve to address these challenges.

Systems engineering is about ensuring that elements of a system work together to achieve an overall objective (INCOSE, 2023, p. 1). Over the past two decades, systems engineering has become increasingly important in the development of systems, as these have grown more complex due to emerging technologies and system interconnectivity (Pyster et al., 2018). Adcock (2024) defines complexity as the difficulty of understanding the behavior of a system or predicting the consequences of making changes to it. He further states that this complexity occurs when a system needs to solve problems or adapt to achieve its objectives in different contexts.

The Company

The researchers conduct this study within a major Norwegian defense contractor. The company is organized into divisions based on subdomains, each specializing in systems for the air, sea or land domain. The focus of this study is positioned within a *defense contractor division*, hereby referred to as DCD.

Problem Description

DCD has experienced significant growth in hires and workload in recent years and plans to further expand its workforce in response to the increasing demand. With emerging technologies and heightened competition, their systems have become more complex and interconnected. DCD has also undergone organizational restructuring to keep up with the fast-paced market. While many view growth as beneficial, it may have unintended consequences. The workload in DCD has been increasing, putting a strain on existing employees. The high workload, growing complexity, and new hires have affected perception of roles and responsibilities within the systems engineering department.

Systems engineering is a young discipline that has evolved over the past 30 years (Watson, 2024). Most systems engineers have an educational background in a specific engineering discipline, primarily mechanical or electrical engineering. After working in a specific discipline for some years, they broaden their knowledge and transition into more integrative positions. This transition is the most common career shift in the systems engineering profession. However, it creates confusion for many, as it differs from the typical career transition of other engineers (Pyster et al., 2018, p. 5). Hutchison et al. (2018) emphasize that a lack of a clear definition of the systems engineer role within an organization reduces the likelihood of the role being fully recognized and effectively utilized. They further state that if the role is not clearly defined, individuals performing the role might struggle to understand how to advance in their careers.

Solution Proposition

This study aims to investigate the roles, experience areas and competencies of systems engineers within DCD to gain an understanding of the current competency levels and developmental needs, as well as provide support in strengthening the systems engineering role. To cover relevant knowledge areas, this study applies the π-shaped model. This model encompasses competency areas in which systems engineers are expected to have knowledge. There are various approaches for investigating how to strengthen role definition, but this study focuses on the roles and competency areas. Whitcomb et al. (2022) state that organizations must have clear definitions of competencies to establish and maintain an effective systems engineering workforce.

Research Questions

This study intends to answer the following research questions:

RQ1: What factors contribute to the challenges in defining the systems engineering role within DCD?

RQ2: How do the competencies of systems engineers in DCD align with the π-shaped model?

Research Methodology

Industry-As-Laboratory

This study applies an industry-as-laboratory approach, conducting research within an industrial setting that serves as the test environment (Potts, 1993). This approach strengthens the connection between industrial needs and academic research by ensuring that the results are feasible and practically relevant (Heemels & Muller, 2020). The researcher works part-time in DCD, allowing valuable insight into current practices. Figure 1 presents the research design for this study.

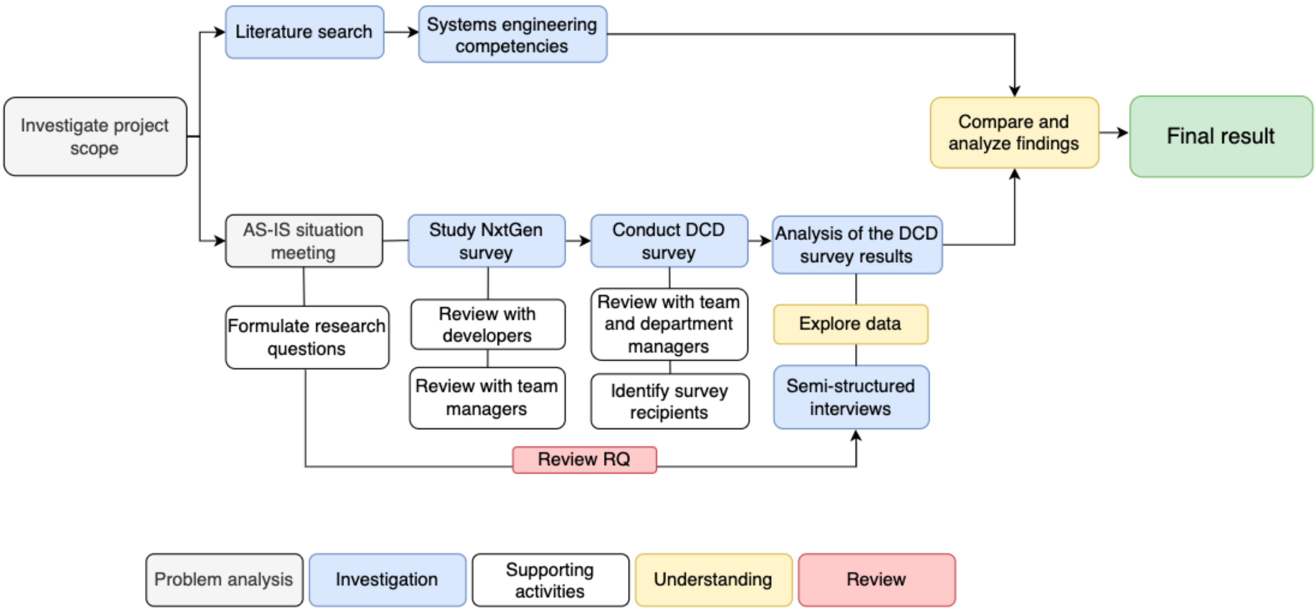

Figure 1. Visualized Research Design

Survey Approach

To gain a deeper understanding and contextualize the results, the researcher developed the DCD survey based on the NxtGen Survey on Systems Engineering Competences (2024). This survey is conducted in the Netherlands within high-tech industries and is based on the roles and competency areas in the INCOSE Competency Framework (2018). Appendix A explains and illustrates this. The researcher has been in contact with the developers of the NxtGen survey and received permission to use it to explore the same topic in a Norwegian context.

The DCD survey consists of 27 questions, divided into four sections: 1) respondent profile, 2) systems engineering roles, 3) systems engineering experience areas, and 4) systems engineering competencies. The questions are a mix of single and multiple-choice, and rating-scale questions. The survey was created using Nettskjema.no, a platform that was recommended by the university and approved by the company. The systems engineering department manager approved the selection of survey recipients. The researcher sent the survey by email within DCD. It was open to the recipients for two weeks, and the researcher sent a reminder after one week.

138 employees across three business units received an invitation to participate, of which 45 responded. However, two respondents did not meet the survey criteria, resulting in 43 respondents. Table 1 represents the population of survey participants across these units. The researcher used the Nettskjema report as the foundation for data analysis. The results were further processed and organized into Excel to create tables and figures, providing a structured overview of the data.

Business Unit	Invited	Re-sponses	Response rate
Survey criteria not met		2	
BU 1	82	27	33%
BU 2	40	11	28%
BU 3	16	5	31%
Total	138	45	33%

Table 1. Survey Business Units and Response Rate

Review Of Surveys

The researcher conducted two separate meetings to review NxtGen and DCD surveys. During the first meeting, the managers and researcher reviewed the NxtGen Survey on Systems Engineering Competencies (2024) to determine whether it was relevant for DCD or not. Minor adjustments were made to align the survey better with DCD. Otherwise, it remains unchanged to ensure a valid comparison. The adjustments included clarifying specific terms, addressing a question about the respondents' division, and adding a role description relevant to DCD. The NxtGen survey developers recommended excluding question 27 (see Appendix B), as it was rushed in formulation and did not provide insightful information. In the second meeting, the researcher presents findings from the DCD survey, and the managers discuss the results in comparison with NxtGen survey results. The researcher finalized the scope of this study and started to investigate existing literature on systems engineering competencies.

Semi-Structured Interviews

To gain a more comprehensive understanding of the selected topic, the researcher conducted semi-structured interviews with two team managers and the department manager. This method of interviewing structures the conversation to address the main topic while allowing the participants to express new perspectives. The purpose of semi-structured interviews is to facilitate a natural conversation between the researcher and the interviewees, creating space to clarify responses, explore meanings, and gain a deeper understanding of the topic (Galletta, 2012, p. 24).

Literature Review

This literature review investigates competency areas important for a systems engineer, how these are developed and why they are important. The main databases used in this literature review are ScienceDirect, IEEE Xplore, USN Oria, Wiley Online Library, and World Scientific. The most frequently used search words were systems engineering competencies, systems engineering competency framework, systems engineering skills and competency definition.

Systems Engineering

The International Council on Systems Engineering (INCOSE, 2019) defines systems engineering as a "transdisciplinary and integrative approach to enable the successful realization, use, and retirement of engineered systems, using systems principles and concepts, and scientific, technological, and management methods". For a system to be successful, it must satisfy the needs of its users, customers, and other stakeholders (SEBok Editorial Board, 2024).

Delivering such a solution requires facilitation, coordination, and guidance to ensure collaboration among different disciplines and experts, from the initial concept phase and through development, production, use, support, and eventual retirement (INCOSE, 2023, p. 1). Few individuals hold the official title of systems engineer, as many perform these activities while operating under other roles (Pyster et al., 2018, p. 3). These include roles such as chief systems engineer, technical manager, systems architect, platform engineer, and verification and validation engineer, roles often performed simultaneously by the same individual (Pyster et al., 2018, pp. 41-51). The broad range of roles underscores the need for a collective understanding of the profession with clear roles and responsibilities (Ryschkewitsch et al., 2009, pp. 81-82).

Competence

Muller (2015) defines competency as the composition of knowledge, skills, abilities, and attitudes (KSAA). Table 2 provides an overview of the KSAA elements and their learning approaches.

KSAA element	Description	Development approach
Knowledge	Facts, concepts, theory	Lectures, reading, exercises
Skills	Apply knowledge to perform specific tasks	Practice, exercises, assignments
Ability	Know when and how to use knowledge and skills in real-world situations	Experience, apply often, use in context
Attitude	Personal attributes, mindset, behavior	Coaching, reflection, self-assessment

Table 2. KSAA elements and their learning approaches (Muller, 2015, pp. 680-681).

Developing competence within systems engineering involves understanding roles, tasks, and the associated KSAA. The KSAA has traditionally been shaped by individual qualities and developed through practical experience. However, emphasis on learning and developing these through education and training programs has increased in recent years (Davidz et al., 2024).

π-shaped Model

Systems engineers are π-shaped, requiring deep expertise within specific disciplines while possessing broad knowledge across multiple fields. Figure 2 illustrates this concept, where the vertical stems represent the in-depth expertise, while the horizontal stems represent the broad knowledge (Pyster et al., 2018, p. 108). The model presents six competence areas.

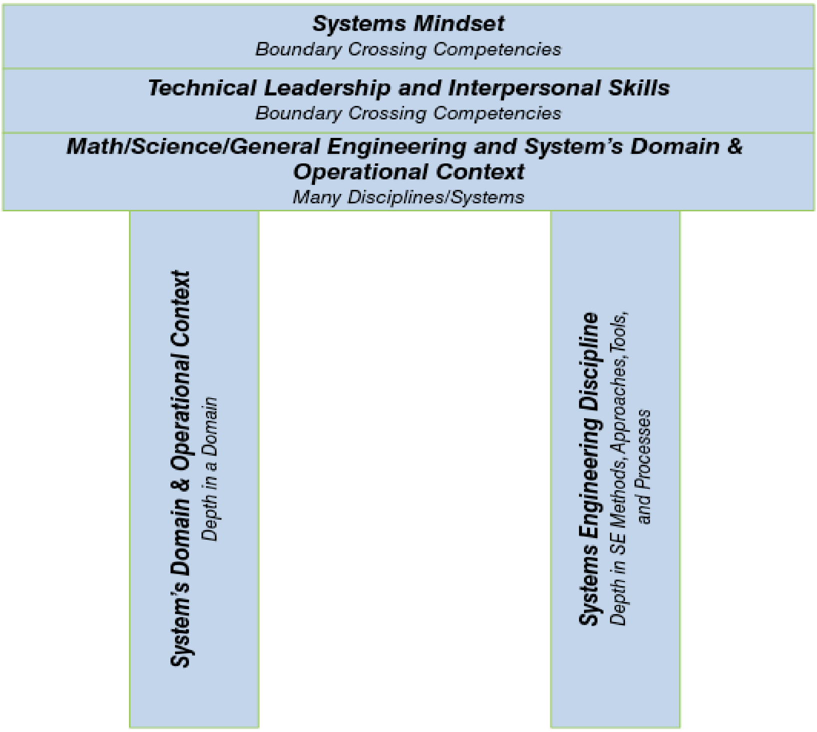

Figure 2. The π-shaped model of systems engineers (Pyster et al., 2018, p. 108).

Area 1. Math/Science/General Engineering

A solid understanding of math, science, and general engineering is essential for an effective systems engineer. Additionally, they must be able to communicate and collaborate with other engineers, making this area of competence important. However, having the same in-depth expertise as those engineers is not required for the role (Pyster et al., 2018, p. 107). Hutchison et al. (2018) define an effective systems engineer as an individual who delivers value by performing systems engineering tasks in roles assigned by the company.

Area 2. System’s Domain & Operational Context

Systems engineers need both deep and broad knowledge in this area. Deep knowledge within a specific system, technology, or engineering discipline, and broad knowledge for the overall understanding of the system. Familiarity with the system, technology, and its operational context enhances the systems engineer's ability to handle complexity and adapt effectively. This combination enables systems engineers to make informed trade-offs and align technical solutions with organizational objectives (Hutchison et al., 2018, pp. 25-26).

Area 3. Systems Engineering Discipline

The second vertical stem represents the deep knowledge in the systems engineering discipline. Various tools, methods, and skills are required to develop and manage a system throughout its life cycle (Pyster et al., 2018, p. 108). A systems engineer is competent in the art and science of balancing technical, cost, and organizational factors in the development of complex systems. They focus on the technical and business needs, intending to deliver a quality solution that meets required needs, functions as intended, and minimizes potential unintended consequences (Hirshorn et al., 2017, p. 3). Therefore, it is important to include them in all life cycle phases (Forsberg & Adcock, 2024). Forsberg & Adcock (2024) state that practitioners must stay up to date on trends that influence their work. INCOSE Vision 2035 (2023) highlights model-based systems engineering as an emerging trend in the coming years.

Area 4. Systems Mindset

Systems engineers must have a paradoxical mindset, which means balancing various views and shifting seamlessly from one perspective to another. This area of knowledge focuses on how systems engineers think, interpret, and approach tasks, with an integrative and holistic perspective beyond traditional engineering. An important skill to manage these tasks is systems thinking (Hutchison et al., 2018, pp. 29-30). Systems thinking is the primary skill differentiating systems engineers from other engineering disciplines (Frank, 2012, p. 273). Swales et al. (2011) conducted a study in cooperation with the Defence Science and Technology Laboratory in the UK, which found that emotional intelligence was the most significant predictor of systems thinking.

As early as 2003, Riemer highlighted the importance of integrating emotional intelligence in engineering education to improve professional skills and career opportunities. He argued that engineering education is too traditional, overly focused on technical problem-solving and that engineers are often stereotyped as emotionally unintelligent men (Riemer, 2003, p. 191). He further states that emotional intelligence makes engineers more adaptable, collaborative, and better equipped to meet workplace challenges. Emotional intelligence can help individuals understand information and ideas from others, connect with wider networks, and reduce perceived barriers. This skill can be trained and developed (Beasley et al., 2019, p. 305).

Area 5. Interpersonal Skills

A systems engineer must be able to build a professional network, as they collaborate across several disciplines and are an important link between internal and external stakeholders. They need skills such as listening, communication, understanding others' points of view, and working effectively within teams. In order to establish a shared understanding, systems engineers must be able to make themselves understood - verbally, in writing, and through documentation. Additionally, they need to balance technical, managerial, and social considerations (Hutchison et al., 2018, pp. 31-32).

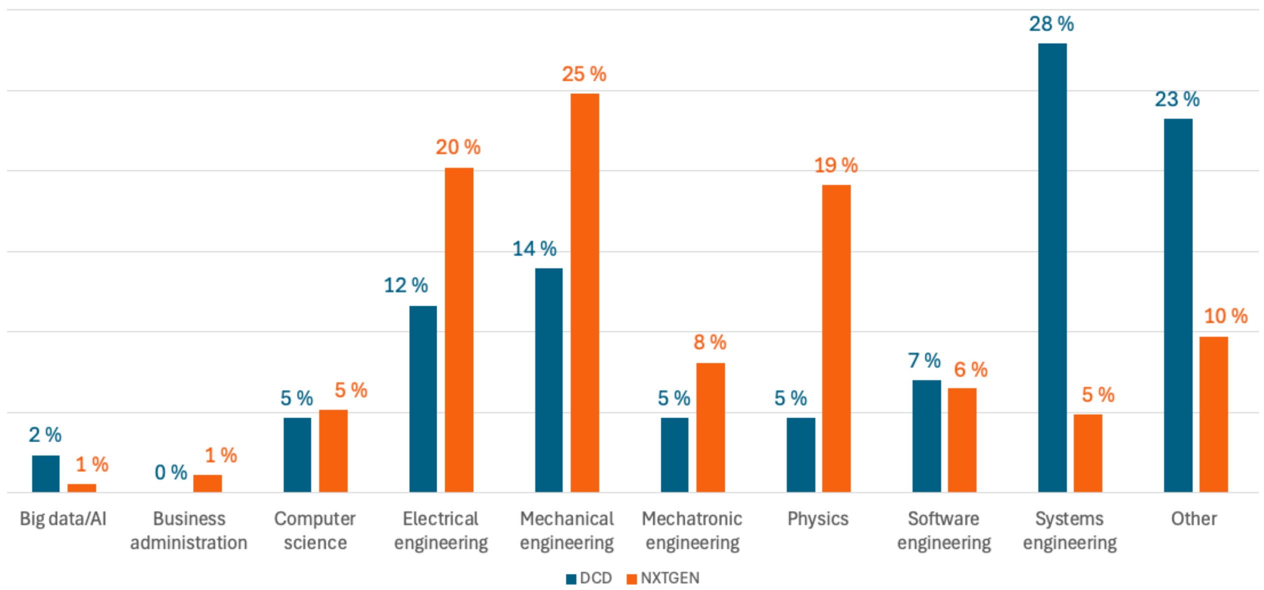

Figure 3. Educational background

Area 6. Technical Leadership

Davidz (2024) states that leadership is important in technical projects and programs, but is overlooked in traditional engineering programs, as it does not address this area. Technical leadership in systems engineering contributes to better performance, a shared understanding, problem-solving, innovation, and learning. Transformational leadership involves achieving objectives through team building, knowledge sharing, building trust, and developing a shared vision. Emotional intelligence is closely associated with transformational leadership (Davidz, 2024). Goleman (1998) identified five categories of competence regarding leadership and emotional intelligence: self-awareness, self-regulation, motivation, empathy, and social skills.

Results From Survey

Company survey results

This chapter presents the results from the survey conducted within DCD and compares them to findings from the NxtGen survey. The researcher wanted to gain insights into the current status of competencies and roles in DCD, and compare the Norwegian high-tech industry with the Netherlands, to be able to place the results in a broader context. In Figure 3 and 4 in this section, the blue columns represent responses from DCD, while the orange columns represent NxtGen responses. The survey includes questions related to the systems engineering role, relevant competencies, and self-assessment of individual competency levels.

The first section of the survey gathered information about the respondents, including their educational background, and general and systems engineering-related work experience. In DCD, 33% reported a background in systems engineering. Conversely, in the NxtGen survey, this was less common (5%). Figure 3 presents the educational background. The surveys included an "Other" option, where participants could specify their educational background if the listed alternatives did not apply. In DCD, two additional respondents reported having a master's degree in systems engineering. These responses are included in the total number and therefore differ from the number represented under systems engineering (28%) in Figure 3.

Figure 4 illustrates the distribution of the respondents' years of general and systems engineering-related work experience. DCD has more individuals with 0-5 years of general work experience than NxtGen. In both surveys, the primary distribution of participants has over 20 years of general work experience. Regarding systems engineering-related work experience, similar trends appear in both surveys, with most respondents having 0-5 years of experience.

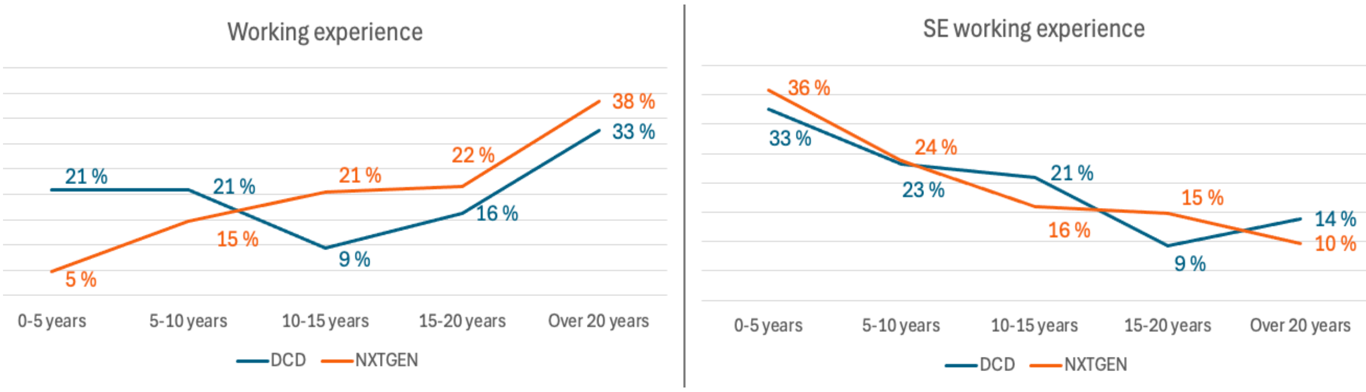

Figure 4. General and Systems Engineering working experience DCD and NxtGen

Additionally, the survey investigated systems engineering experience areas, where the participants could select multiple answers. The highest experience area in DCD was requirements engineering, with 93%. This result shows similarities with the NxtGen survey, where this experience area was also the highest, with 88%.

The next section of the survey investigated the participants' competence level across the five competency areas defined in the INCOSE Competency Framework. In addition, the survey asked the participants to rank the relevance of competencies in their current position and to choose the top three competencies to develop in the short term to become more effective or take the next step in their career.

Competence Level

The overall level of competency is at the practitioner or lead practitioner level in both surveys.

Figure 5 and 6 represent an extract of specific competency levels from various categories within the INCOSE Competency Framework for DCD and NxtGen. Technical leadership and emotional intelligence have the highest number of experts, while finance has the weakest competency level, followed by life cycle in DCD. 62% of the respondents ranked their competence level as a practitioner or lower on systems modelling and analysis. As shown in Figure 6, similar trends appear in the NxtGen survey. The most significant difference is that NxtGen has more experts on technical leadership and systems thinking than on emotional intelligence. In the systems modelling and analysis in the NxtGen survey, 70% ranked their competence level as a practitioner or lower.

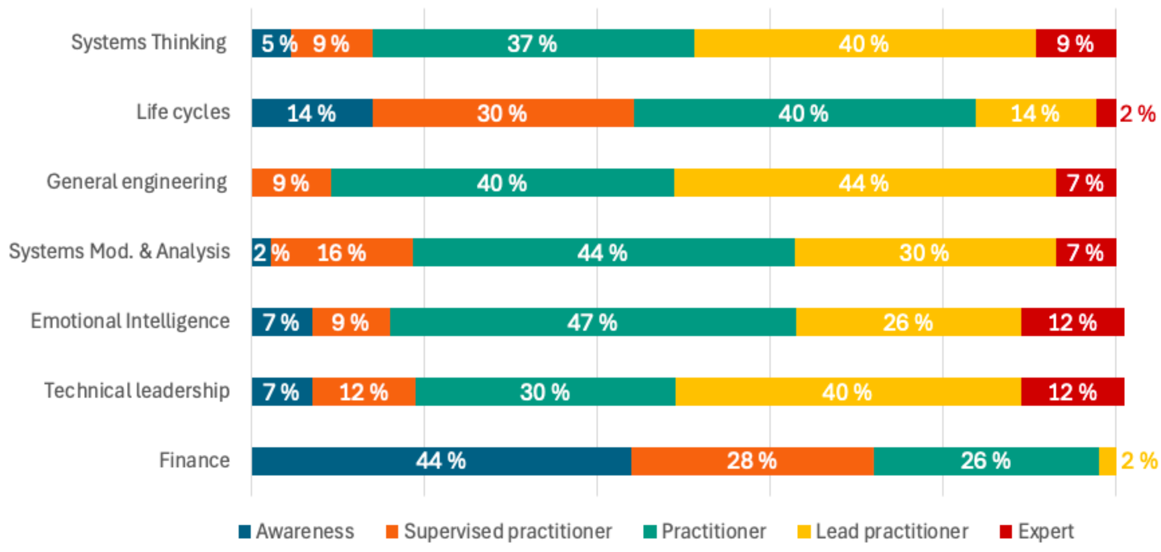

Figure 5. Distribution of competency levels DCD

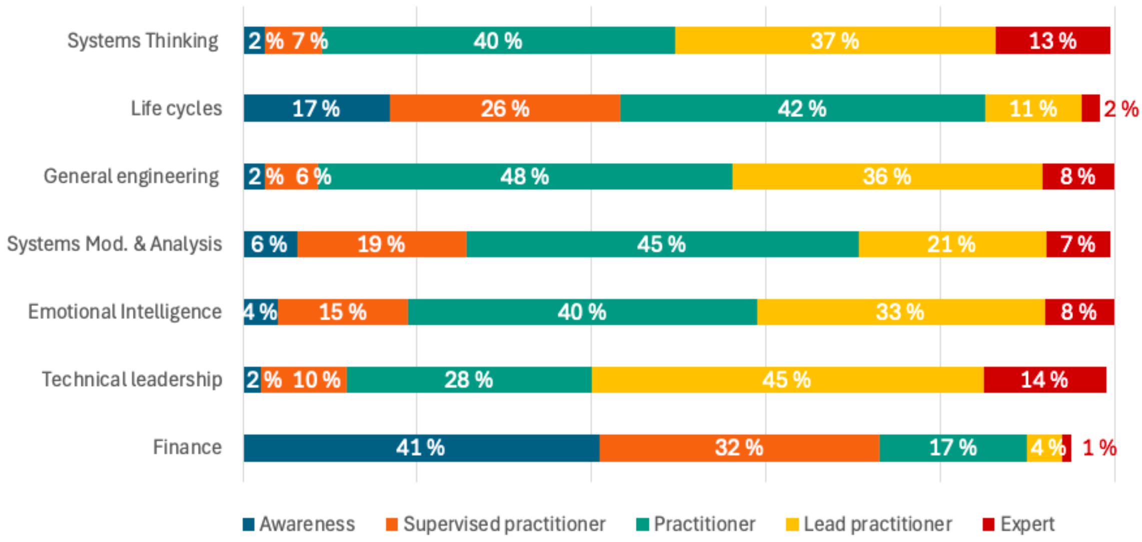

Figure 6. Distribution of competency levels NxtGen

Relevance of competency

The participants in DCD ranked general engineering, technical leadership, communication, systems thinking, and finance as relevant competencies for their current position. The least relevant were life cycle, emotional intelligence, and logistics. These competencies fall under core, professional, and integrating competencies in the INCOSE Competency Framework. Systems thinking, communication, and technical leadership were also relevant for the respondents in NxtGen. Finance ranks low, as it was the third most relevant out of four options. Life cycle was the least relevant competency in its category in the NxtGen survey.

Top three competencies for development

In DCD, systems modelling and analysis ranks significantly higher than the rest of the competencies, with a response rate of 74%. Additionally, systems thinking and life cycles are competency areas participants want to develop. Systems modelling and analysis were also among the highest ranked competency areas in NxtGen to develop (52%), along with capability engineering and systems thinking.

In the category of professional competencies, DCD wanted to develop technical leadership and communication skills the most, while ethics and professionalism, and emotional intelligence were the least important. NxtGen ranks negotiation and technical leadership highest, and ethics and professionalism lowest. Emotional intelligence was the third-lowest competency desired to develop in NxtGen. Project management ranks highest in DCD in the integrating competency category, while NxtGen wanted to develop finance competency the most. For DCD, finance ranks the lowest in development needs.

Table 3 summarizes and presents some interesting findings from the DCD survey. The table summarizes specific competencies, the level at which the respondents ranked themselves, relevance for the current position, and the development need.

Competency	Compe-tency level	Rele-vance	Devel-opment need
Systems thinking	High	High	High
Life cycles	Low	Low	High
Systems Model-ing & Analysis	Low	High	High
Finance	Low	High	Low
Emotional Intelli-gence	High	Low	Low

Table 3. Findings from the survey conducted within DCD.

Results From Semi-Structured Interviews

Interview context and participants

To ensure the validity of the survey findings, the researcher interviewed two team managers and one department manager from the systems engineering department in DCD. The team managers are each responsible for their respective groups within DCD. One of them has been with the company since 2011, and the other since 2019. The department manager started working as a project manager in the company in 2021 and has led the systems engineering department since 2023. The researcher chose these interviewees for their involvement in competence planning, experience within systems engineering, and insights into the relevance of various roles and competencies within DCD.

Current status in the company

The researcher wanted to better understand situation within DCD regarding the definition and perception of the role of systems engineers. The interviews started with an informal conversation about these topics. The managers provided the researcher with an internal DCD document explaining a systems engineer's roles and responsibilities. Systems designer, systems architect, and technical manager are some of the roles a systems engineer might hold within DCD. After reviewing the document with the team managers, it was evident that the company places significant emphasis on the technical aspect, as the description of the roles mainly covers this area. Additionally, none of the roles in the document had the title of *systems engineer*, as this was often confused with an engineer providing advanced technical support for a system.

The team managers state that establishing and communicating systems engineering as a possible career path within the company is crucial, as recruitment to the department will become important in the coming years due to the increasing growth. Some stakeholders in DCD may perceive the systems engineering department as abstract and unclear, and there is a saying that systems engineers mainly work with requirements and documentation. The systems engineers are assigned tasks they feel are outside their scope, but no one takes responsibility for them, resulting in the systems engineers having to do them. The department manager suggests that this may be because the role has no clear boundaries. One team manager argues that the various roles and responsibilities can confuse employees from other departments, making it difficult to understand what the systems engineering role fully involves.

The managers acknowledge that DCD needs to strengthen the role of systems engineers. In January 2025, the employees expressed the wish to define the role better in a team meeting, as well as in an employee survey conducted in the fall of 2024. The systems engineering role is context-dependent in DCD, and with the right competencies, individuals are able to navigate what is relevant to the role and what is not, the Department Manager states. DCD is currently working on a career development plan. This plan provides descriptions of roles and the competencies required in the systems engineering position. The managers need input on what competencies are important and need further development.

One team manager describes a shift in the company. From 2011 to 2019, the systems engineer role felt more recognized. There were good processes and training for the role, and communication with other stakeholders was easier. Many of the existing employees had been in the company for several years, which allowed them to build solid networks and become key contributors in raising awareness of the systems engineering role. Over the years, DCD has experienced restructurings and loss of experienced resources and has recruited many new employees. The systems that DCD is developing are becoming increasingly more complex due to technology and interconnections, and the department manager states that the more complex a system becomes, more experts are needed.

DCD is transitioning from a project-based to a product-oriented approach, meaning that the organization will focus on product teams rather than project teams. This shift requires systems engineers to adapt their ways of working, states the managers.

General views on the systems engineering role and competencies

All interviewees underpin that the systems engineering department has many competent, knowledgeable, and effective employees. But with the high workload and more to come, they see a need to strengthen the role definition and map competencies to meet future challenges. One of the team managers mentions that the current way of working in DCD can hinder full utilization of the systems engineer competencies. As they are often involved late in projects, and stay on late after delivery to complete remaining tasks. The interviewee further states that DCD measures a project based on immediate delivery, not how the systems work throughout its operational life.

The department manager argues that systems engineering is an experience-based profession, especially within DCD. It is a large, high-tech company with diverse employees and stakeholders. The company uses many abbreviations in everyday language and formal documentation, which may feel overwhelming and unclear for new employees. Systems engineers must also be comfortable working in environments without fixed frameworks, handling ambiguity, adapting to project needs, and responding to unexpected changes. Therefore, a strong understanding of the system and the company is essential. However, it takes time to build up these abilities and skills.

Building a solid network is vital to navigate within DCD. The team managers recognize that the most effective systems engineers have often held other positions within the company before entering the systems engineering department. They have established a network within the company and have knowledge about the system. This foundation makes it easier to know who to ask, where to find the necessary information, and what the system needs to function as intended. The interviewees emphasize that employees who have been or are currently taking the industrial master's program seem to become comfortable in the role quickly. This is a collaborative program over three years between the University of South-Eastern Norway and the industry in the region. The students combine part-time work with part-time studies. The managers state that the students start slowly by getting to know parts of the system, having time to establish a network, and avoiding feeling the pressure to perform.

Development potential

The researcher presents and discusses findings from Table 3 with the interviewees, to investigate whether it provides a true representation. Some responses from the DCD survey raised questions among the managers, as not all appeared coherent or aligned.

The department manager commented on the low score on relevance in emotional intelligence, further stating that this competency area is highly important in collaboration, teamwork, and understanding others' behavior, which are essential in the systems engineering role. One of the Team Managers said that individuals with strong social and emotional intelligence skills tend to accomplish tasks more effectively within the team. The manager states that it is uncertain whether these individuals are aware of their skills and are actively working on them or if they perform these unconsciously.

The finance and life-cycle responses in the survey appeared inconsistent, and the connection between competence level, relevance, and developmental needs did not align rationally. The managers state that it is important for a systems engineer to have a good financial understanding, as it enables better technical decision-making and can contribute to scoping the project. However, the procurement department handles the financial aspect, and therefore has minimal focus within the systems engineering department.

The focus and strategies on life cycles within the company have potential for improvement. The interviewees strongly claim that this is a great need in DCD and in the systems engineering department. The company has focus on meeting time and cost constraints, and life cycle is therefore not the primary focus. One of the team managers says this focus is due to stress and pressure in the market. Even though the company knows that the customer will return in a few years to assemble more equipment, it is typically addressed when the problem arises, and not proactively. This creates significant work for the systems engineers, as integration is not always straightforward.

Discussion

This section discusses earlier findings in this study, aiming to answer the research questions.

RQ1: What factors contribute to the challenges in defining the systems engineering role within DCD?

Hutchison et al. (2018) emphasizes the importance of clearly defining the systems engineering role within organizations. A lack of clarity might result in negative consequences, such as a lack of acknowledgement and not utilizing the role fully. It can also affect an individual's ability to advance their career further. Ryschkewitsch (2009) supports the importance of clear roles and responsibilities. He states that it is important to have a mutual understanding of the role due to its broad range. Based on the team meeting from 2025 and the employee survey from 2024, is it evident that employees in the systems engineering department in DCD want a stronger definition of their role.

DCD has experienced significant growth in recent years due to the unstable geopolitical climate, and the Norwegian defense industry will be an important contributor to addressing the increasing demand in the coming years. This statement indicates that DCD will continue to experience growth and is in need of systems engineering resources. Systems engineering is a young discipline compared to traditional engineering, Watson (2024) states. This is evident in both the DCD and NxtGen survey results, where the majority have over 20 years of work experience, yet most participants report only 0-5 years of systems engineering work experience. These findings highlight that the systems engineering discipline is not only young in the Norwegian high-tech industry, but also in the Netherlands.

The department manager states that the discipline is experience-based. Davidz et al. (2024) support this, emphasizing that competence within systems engineering has traditionally been shaped through practical experience. In large companies with complex systems, three years may not be enough to be fully comfortable in this role. The literature indicates that the role of systems engineering is demanding due to the broad areas of knowledge it encompasses and requires (Pyster et al., 2018, p. 108).

DCD has undergone organizational restructurings in recent years to keep pace with the previously mentioned rapid developments and to deliver more integrated system solutions. One of the Team Managers described a change from being a small systems engineering department with key resources, established processes, and good communication among stakeholders, to a bigger department where these elements have gradually faded. New hires in all parts of the division, restructurings, and loss of experienced systems engineers could be a contributing factor to why the systems engineering role has gradually lost its establishment. This supports the department manager's statement that systems engineering is experience-based. According to the literature, establishing relevant competence takes time, as these develop through practical experience (Davidz et al., 2024). Even though there has been greater emphasis on learning these through education and training programs recently, it is reasonable to expect that developing these within complex systems takes time.

Pyster et al. (2018) states that few individuals hold the official systems engineer title, and many perform these tasks under other roles. This is also the case in DCD, based on findings from the internal role and responsibilities document, where the title “systems engineer” is not used because it gets confused with other roles. Additionally, Pyster et al. (2018) emphasize that systems engineers often have a different career transition than traditional engineers, which can create confusion. In the semi-structured interview, one of the managers said that systems engineers are often perceived as requirements engineers and are assigned tasks related to this in the form of documentation. In DCD, requirements engineering is the most experienced area, with 93%. This finding supports the managers’ statement and indicates that there might not be a collective understanding of the systems engineer’s role within the company. The literature argues that systems engineers hold a broad interdisciplinary competence, extending beyond the association of "those who handle requirements" in DCD.

DCD will transition from a project-based to a product-oriented organization in the coming years. This transition will change how systems engineers work, as they will become part of a product team and work with specific parts of the system. This transition might eliminate the issue of systems engineers being involved too late in projects.

One of the managers believes that the role of systems engineering will become important in areas where it has been previously overlooked due to the rising demand, systems complexity, and interconnectivity. They further state that the more complex a system becomes, the more experts are needed. However, expecting one role or individual to ensure that elements of a system work together, while understanding the behavior of a system or predicting consequences when making changes to it, is not feasible. Especially considering that the workforce has limited experience.

This section identifies several factors contributing to the challenges in defining the systems engineer role within DCD: a young workforce in an experience-based discipline; a broad variety of role titles leading to confusion; a lack of collective understanding of the role within the company; and rapid growth, new hires and restructurings.

RQ2: How do the competencies of systems engineers in DCD align with the π-shaped model?

Whitcomb et al. (2022) emphasize the importance of having clear competency definitions and frameworks to establish and maintain an effective workforce. The π-shaped model can provide input into a systems engineering framework for DCD, to gain an overview of the areas in which systems engineers possess competence. Such insights can also be helpful for recruitment and competence development initiatives.

Area 1: Math/Science/General Engineering. Results from the DCD survey indicate that this area is well covered. Over 50% of the participants rated their competence level on general engineering at lead practitioner or expert (see Figure 5). They also rated general engineering as relevant for their current position. The majority have a systems engineering background, followed by electrical or mechanical engineering. This supports the statement by Pyster et al. (2018) that most systems engineers have an educational background in a specific engineering discipline.

Area 2: System’s Domain & Operational Context. The survey did not cover the respondents' competency regarding the systems DCD develop and its operational context. But based on the semi-structured interviews, the managers state that the current systems engineers in the department have good knowledge and are effective. Considering that several respondents have a systems engineering education, and there are many who might have taken the industrial master's program, the horizontal stem is likely well covered. As systems engineering is an experience-based discipline, developing deep knowledge in the vertical stem will take time.

Area 3: Systems Engineering Discipline. There are significantly more DCD employees with a systems engineering background (33%) than NxtGen (5%). The high amount in DCD is due to the industrial master's program. Forsberg & Adcock (2024) argue the importance of including systems engineers in all life cycle phases but based on findings from the survey and semi-structured interviews, this is not the case within DCD. According to the survey results, life-cycle is one of the areas with the lowest competency levels. Findings from the semi-structured interview support this, where the managers acknowledge that DCD have development potential in this area. This indicates that DCD should focus on creating strategies for life-cycle, developing this competency, and making use of this knowledge. These actions could highlight the role as an integrative approach and make it more visible in areas where it has previously been overlooked.

From the survey results, finance was rated low in competence, high in relevance, and low in developmental need. This finding supports the manager's statement that finance has been a low priority in the department, as procurement handles it. However, literature argues that knowledge in this area is important in the role of a systems engineer, balancing technical, cost, and organizational factors (Hirshorn et al., 2017). The DCD survey participants want to develop their competency in systems modelling and analysis. INCOSE (2023) states that systems engineers must stay updated on future trends, and that systems modelling is an emerging trend in the future. This finding shows that the survey participants are updated and want to develop their knowledge in this area. However, this can indicate preference for developing competence in traditional engineering tasks, rather than in areas outside core engineering practice, like finance.

Area 4: Systems Mindset. Systems thinking differentiates systems engineering from other engineering disciplines, according to Frank (2012). Swales et al. (2011) found evidence that emotional intelligence strongly connects with systems thinking. The department manager raised questions regarding these responses, as this competency was rated high in competence level, but low in both relevance and development need. Riemer (2003) and Beasley et al. (2019) emphasize that emotional intelligence is important in collaboration, connection with networks, and understanding others' behavior. This indicates that the competency level of emotional intelligence in DCD is high, but needs further attention as it is highly relevant in the profession.

Area 5: Interpersonal skills. This area is important in the role of being a systems engineer, as they collaborate and communicate across several disciplines (Hutchison et al., 2018). According to survey findings, communication is a relevant competency in DCD, and the participants want to further develop it. The findings indicate that this competency area should be a focus for further development, while also providing input for the team managers in the career development plan.

Area 6: Technical Leadership. This area has a high level of competence among the participants in the DCD survey, as well as being relevant for them, they wish to develop it further. This area is often overlooked in traditional engineering programs and is highly relevant to emotional intelligence, according to Davidz (2024). Based on the internal DCD role and responsibilities document and the semi-structured interviews, there is a strong focus on the technical aspect in the company. While the literature suggests that this area is relevant to leadership and emotional intelligence, the DCD survey participants may perceive it as more technical than the literature suggests. For example, one of the role descriptions in the DCD document was for a technical manager, and this term can be confused with technical leadership.

Conclusion

This study investigates the role and competencies of systems engineers within a large Norwegian defense contractor and compares the results with a survey conducted within high-tech industries in the Netherlands. The main findings from this comparison are that there are many similar trends in both surveys regarding competency levels, relevance, and development needs of competencies. The most notable difference is that DCD has a higher number of individuals with a systems engineering background than those who participated in the NxtGen survey. This study identifies several factors contributing to the challenges in defining the systems engineer role within DCD: a young workforce within an experience-based discipline; a broad variety of role titles leading to confusion; a lack of collective understanding of the role within the company; and rapid growth, new hires and restructurings that have dissolved the previously established understanding of the systems engineering role.

To support strengthening the role definition within the company, this study compares current competency levels with the knowledge areas in the π-shaped model. The main findings are that some areas are well covered, while others lack competency, especially in areas where life cycles and finance are important. The researchers recommend investigating the factors identified in the first research question, and mitigating them. Further, using competency findings to strengthen the role definition and using the findings in the development needs to increase the competency levels.

Limitations

The NxtGen survey is not tailored to the defense industry or DCD. Therefore, some competency areas and terminology may differ from those used in DCD. The different areas and terminology can lead to misunderstandings, resulting in inaccurate or incorrect responses. The researcher did not create the survey, which limits control over the questions and wording. This research method relies on participation from employees within the company. Systems engineers in DCD have a high workload and limited resources, which affects how much time and effort the employees devote to other tasks. The researcher received 45 survey responses and conducted semi-structured interviews with three systems engineering managers, which is a limited amount of data to support strong conclusions.

Future Work

DCD should develop a framework for the competencies of a systems engineer. This framework can help with gaining a collective understanding of the role and what it encompasses. Additionally, the findings of developmental needs from the survey should be further examined and used as input in the career development plan to help current systems engineers to be more effective or make a next step in their careers.

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References

Adcock, R. (2024). Complexity in SEBoK Editorial Board. *The Guide to the Systems Engineering Body of Knowledge (SEBoK)*, v. 2.11, N. Hutchison (Editor in Chief). Hoboken, NJ: The Trustees of the Stevens Institute of Technology. Retrieved April 15th 2025 from https://sebokwiki.org/wiki/Complexity

Beasley, R., Gelosh, D. S., & Pickard, A. C. (2019). Professional Competencies – the soft skills to give Systems Engineers a hard edge. *INCOSE International Symposium*, *29*(1), 301–317. https://doi.org/10.1002/j.2334-5837.2019.00605.x

Davidz, H. (2024). Technical Leadership in Systems Engineering in SEBoK Editorial Board. *The Guide to the Systems Engineering Body of Knowledge (SEBoK)*, v. 2.11, N. Hutchison (Editor in Chief). Hoboken, NJ: The Trustees of the Stevens Institute of Technology. Retrieved April 11th 2025 from https://sebokwiki.org/wiki/Technical_Leadership_in_Systems_Engineering

Davidz, H., Fairley, D., & Hilburn, T. (2024). Roles and Competencies in SEBoK Editorial Board. *The Guide to the Systems Engineering Body of Knowledge (SEBoK)*, v. 2.11, N. Hutchison (Editor in Chief). Hoboken, NJ: The Trustees of the Stevens Institute of Technology. Retrieved April 11th 2025 from https://sebokwiki.org/wiki/Roles_and_Competencies

Forsberg, K., & Adcock, R. (2024). System Life Cycle Models in SEBoK Editorial Board. *The Guide to the Systems Engineering Body of Knowledge (SEBoK)*, v. 2.11, N. Hutchison (Editor in Chief). Hoboken, NJ: The Trustees of the Stevens Institute of Technology. Retrieved April 23rd 2025 from https://sebokwiki.org/wiki/System_Life_Cycle_Models

Frank, M. (2012). Engineering Systems Thinking: Cognitive Competencies of Successful Systems Engineers. *Procedia Computer Science*, *8*, 273–278. https://doi.org/10.1016/j.procs.2012.01.057
Galletta, A. (2012). *Mastering the semi-structured interview and beyond : from research design to analysis and publication* (1st ed.). New York University Press.
Goleman, D. (1998). The emotionally competent leader. *Health Forum Journal*, 41(2), 38–76.
Government of Norway. (2024, October 10). *The government earmarks 967 million NOK to strengthen Norway's defense industry*. https://www.regjeringen.no/en/aktuelt/regjeringen-oremerker-967-millioner-for-a-styrke-norsk-forsvarsindustri/id3058695/
Government of Norway. (2026, March 27). *Government to provide additional NOK 115 billion to strengthen Long-term Defence Plan.* https://www.regjeringen.no/en/whats-new/government-to-provide-additional-nok-115-billion-to-strengthen-long-term-defence-plan/id3155063/
Government of Norway. (2026, February 24). *Long-term support for Ukraine is vital.* https://www.regjeringen.no/en/whats-new/long-term-support-for-ukraine-is-vital/id3150045/
Heemels, M. & Muller, G. (2020). *Five Years of Multi-Disciplinary Academic and Industrial Research; Lessions Learned.* Retrieved from Gaudisite: https://www.gaudisite.nl/BodercLessonsLearnedPaper.pdf
Hirshorn, S. R., Voss, L. D., & Bromley, L. K. (2017). *NASA systems engineering handbook* (Rev. 2; NASA/SP-2016-6105 Rev 2). NASA. https://ntrs.nasa.gov/citations/20170001761
Hutchison, N. A. C., Verma, D., Burke, P., Clifford, M., Giffin, R., Luna, S., & Partacz, M. (2018). *Atlas 1.1: An update to the theory of effective systems engineers* (SERC-2018-TR-101-A). Systems Engineering Research Center. https://apps.dtic.mil/sti/citations/AD1046509
INCOSE. (2018). *Systems Engineering Competencies Framework* (INCOSE-TP-2018-002-01.0). International Council on Systems Engineering (INCOSE).
INCOSE. (2019). *Systems engineering and system definitions* (INCOSE-TP-2020-002-06, Version 1.0). International Council on Systems Engineering (INCOSE).
INCOSE. (2021). *Systems Engineering Vision 2035*. International Council on Systems Engineering. https://www.incose.org/sevision
INCOSE. (2023). *Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities,* (5th Edition). John Wiley & Sons (US).
Muller, G. (2015). Reflective Practice to Connect Theory and Practice; Working and Studying Concurrently. *Procedia Computer Science*, *44*(C), 679–688. https://doi.org/10.1016/j.procs.2015.03.008
NxtGen Hightech. (2024). *NxtGen Survey on Systems Engineering Competences*. Unpublished report.
Potts, C. (1993). Software-engineering research revisited. *IEEE Software*, 10(5), 19-28. https://doi.org/10.1109/52.232392
Pyster, A., Hutchison, N., & Henry, D. (2018). *Paradoxical Mindset of Systems Engineers - Uncommon Minds, Skills, and Careers* (1st ed.). John Wiley & Sons.
Riemer, M. J. (2003). Integrating emotional intelligence into engineering education. *World Transactions on Engineering and Technology Education*, *2*(2), 189–194.
Ryschkewitsch, M., Schaible, D., & Larson, W. (2009). The art and science of systems engineering. *Journal of Systemics, Cybernetics and Informatics*, *7*(5), 81–100. https://doi.org/10.1142/S1793966609000080
SEBoK Editorial Board (2024). *The Guide to the Systems Engineering Body of Knowledge (SEBoK)*, v. 2.11, N. Hutchison (Editor in Chief). Hoboken, NJ: The Trustees of the Stevens Institute of Technology. Accessed [DATE]. www.sebokwiki.org. BKCASE is managed and maintained by the Stevens

Institute of Technology Systems Engineering Research Center, the International Council on Systems Engineering, and the Institute of Electrical and Electronics Engineers Systems Council.

Swales, S., Wright, J., & Oxenham, D. (2011). *Systems skills development – The yellow brick road approach*. UK Systems Society. https://www.bristol.ac.uk/media-library/sites/eng-systems-centre/migrated/documents/simon-swales.pdf

Watson, M. (2024). Systems Engineering Principles in SEBoK Editorial Board. 2024. *The Guide to the Systems Engineering Body of Knowledge (SEBoK)*, v. 2.11, N. Hutchison (Editor in Chief). Hoboken, NJ: The Trustees of the Stevens Institute of Technology. Retrieved May 3rd 2025 from https://sebokwiki.org/wiki/Systems_Engineering_Principles

Whitcomb, C., White, C., & Khan, R. (2022). Using the INCOSE Systems Engineering Competency Framework. *Insight (International Council on Systems Engineering)*, *25*(3), 17–29. https://doi.org/10.1002/inst.12394

Appendix A

INCOSE Competency Framework

The INCOSE Competency Framework guides practitioners and recipients to identify knowledge, skills, and abilities related to the role of SE (INCOSE, 2018, p. 6). This framework can be used in recruitment, individual assessment, job description development, or training and education (Whitcomb et al., 2022, pp. 20-21). To be an effective SE, an individual will need supporting skills, techniques, and domain knowledge (INCOSE, 2018, p. 8).

The framework consists of five categories – core, professional, management, technical, and integrating competencies. Each category is briefly described, highlighting its relevance and consists of specific competencies related to the SE role (INCOSE, 2018, p. 10). For each competency, a set of effective indicators of knowledge and experience is provided, organized into five levels of increasing competence, from awareness, supervised practitioner, practitioner, lead practitioner, to expert (Whitcomb et al., 2022, p. 18).

CORE COMPETENCIES		PROFESSIONAL COMPETENCIES		MANAGEMENT COMPETENCIES		TECHNICAL COMPETENCIES	
Core competencies underpin engineering as well as systems engineering.		Behavioral competencies well-established within the Human Resources (HR) domain. To facilitate alignment with existing HR frameworks, where practicable, competency definitions have been taken from well-established, internationally-recognized definitions rather than partial or complete re-invention by INCOSE.		The ability to perform tasks associated with controlling and managing Systems Engineering activities. This includes tasks associated with the Management Processes identified in the INCOSE SE Handbook.		The ability to perform tasks associated primarily with the suite of Technical Processes identified in the INCOSE SE Handbook.	
Systems Thinking	The application of the fundamental concepts of systems thinking to systems engineering;	Communications	The dynamic process of transmitting or exchanging information;	Planning	Producing, coordinating and maintaining effective and workable plans across multiple disciplines;	Requirements Definition	To analyze the stakeholder needs and expectations to establish the requirements for a system;
Lifecycles	Selection of the appropriate lifecycles in the realization of a system;	Ethics and Professionalism	The personal, organizational, and corporate standards of behavior expected of systems engineers;	Monitoring and Control	Assessment of an ongoing project to see if the current plans are aligned and feasible;	System Architecting	The definition of the system structure, interfaces and associated derived requirements to produce a solution that can be implemented;
Capability Engineering	An appreciation of the role the system of interest plays in the system of which it is a part;	Technical Leadership	The application of technical knowledge and experience in systems engineering together with appropriate professional competencies;	Decision Management	The structured, analytical framework for objectively identifying, characterizing and evaluating a set of alternatives;	Design for…	Ensuring that the requirements of all lifecycle stages are addressed at the correct point in the system design;
General Engineering	Foundational concepts in mathematics, science and engineering and their application;	Negotiation	Dialogue between two or more parties intended to reach a beneficial outcome where difference exist between them;	Concurrent Engineering	A work methodology based on the parallelization of tasks;	Integration	The logical process for assembling a set of system elements and aggregates into the realized system, product or service;
Critical Thinking	The objective analysis and evaluation of a topic in order to form a judgement;	Team Dynamics	The unconscious, psychological forces that influence the direction of a team's behavior and performance;	Business and Enterprise Integration	The consideration of needs and requirements of other internal stakeholders as part of the system development;	Interfaces	The identification, definition and control of interactions across system or system element boundaries;
Systems Modeling and Analysis	Provision of rigorous data and information including the use of modeling to support technical understanding and decision making.	Facilitation	The act of helping others to deal with a process, solve a problem, or reach a goal without getting directly getting involved;	Acquisition and Supply	Obtaining or providing a product or service in accordance with requirements;	Verification	A formal process of obtaining objective evidence that a system fulfils its specified requirements and characteristics;
		Emotional Intelligence	The ability to monitor one's own and others' feelings and use this information to guide thinking and action;	Information Management	Addresses activities associated with all aspects of information, to provide designated stakeholders with appropriate levels of timeliness, accuracy and security;	Validation	A formal process of obtaining objective evidence that the system achieves its intended use in its intended operational environment;
		Coaching and Mentoring	Development approaches based on the use of one-to-one conversations to enhance an individual's skills, knowledge or work performance.	Configuration management	Ensuring the overall coherence of system functional, performance and physical characteristics throughout its lifecycle;	Transition	Integration of a verified system into its operational environment including the wider system of which it forms a part;
				Risk and Opportunity Management	The identification and reduction in the probability of uncertain events, or maximizing the potential of opportunities provided by them,	Operation and Support	When the system is used to deliver its capabilities, and is sustained over its lifetime.
INTEGRATING COMPETENCIES	This competency group recognizes Systems Engineering as an integrating discipline, joining activities and thinking from specialists in other disciplines to create a coherent whole.	Project Management	Identification, planning and coordinating activities to deliver a satisfactory system, product, service of appropriate quality;	Logistics	The support and sustainment of a product once it is transitioned to the end user;		
		Finance	Estimating and tracking costs associated with the project;	Quality	Achieving customer satisfaction through the control of key product characteristics.		

Appendix B

NxtGen survey questionnaire

1. Are you active in the field of systems engineering/architecting? If so, then we would truly appreciate your input. If not, we thank you for your interest, but then this questionnaire may not be of interest to you.
2. Where are you located?
3. What is your background by education?
4. You filled in other in the previous question about your educational background. What is your educational background?
5. What is your highest level of education?
6. How many years of working experience do you have?
7. How many years of systems engineering related working experience do you have?
8. In which grade is your current position classified?
9. Which of the following systems engineering experience areas (defined according to INCOSE) are relevant for your current function?
10. How do you rate your current competence level regarding core systems engineering principles?
11. How would you rank (from most important, on top of the following list, to the least important, towards the bottom of the list) the relevance of core systems engineering principles for your current position?
12. Which top three core systems engineering principles do you need to develop (on a short run) to be more effective, or make a next step in your career?
13. How do you rate your current competence level regarding professional competencies?
14. How would you rank (from the most important, on top of the following list, to the least important, towards the bottom of the list) the relevance of professional competencies for your current position?
15. Which top three professional competencies do you need to develop (on a short run) to be more effective, or make a next step in your career?
16. How do you rate your current competence level regarding technical competencies?
17. How would you rank (from most important, on top of the following list, to the least important, towards the bottom of the list) the relevance of technical competencies for your current position?
18. Which top three technical competencies do you need to develop (on a short run) to be more effective, or make a next step in your career?
19. How do you rate your current competence level regarding management competencies?
20. How would you rank (from most important, on top of the following list, to the least important, towards the bottom of the list) the relevance of management competencies for your current position?
21. Which top three management competencies do you need to develop (on a short run) to be more effective, or make a next step in your career?
22. How do you rate your current competence level regarding integrating competencies?
23. How would you rank (from most important, on top of the following list, to the least important, towards the bottom of the list) the relevance of integrating competencies for your current function?
24. Which top three integrating competencies do you need to develop (on a short run) to be more effective, or make a next step in your career?
25. Which roles are part of your current position?
26. Which role is most dominant/prominent in your current position?
27. Industry is facing several critical trends. How do you rate the impact of these trends on future required competencies?
28. Do you have any additional remarks or suggestions?