

ArchSkills

**Future proofing systems engineering
competencies**

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ArchSkills

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Author(s)	Ben Pronk, Joana Teixeira, Bas van der Leeuw, Joris van den Aker, Pieter Goosen, Teun Hendriks
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Abstract

The R&D of the high-tech (HT) equipment industry is in a series of transitions towards a more and more agile way of systems engineering, often in combination with the development of software-intensive systems. Transitions include moving from equipment engineering to developing and delivering solutions and services, from *engineering to order* to *configure to order* practices, towards model-based engineering methodologies and platform-based engineering. As the R&D and engineering landscape changes, the role of key system engineering stakeholders, such as architects and integrators, needs to change accordingly, which requires an updated skill and competency set.

This report describes the steps that were taken to analyse the impact of the transitions sketched above on the required competency set of future system architects and integrators, and consolidates the results, aiming to expand, update and tailor current state-of-the-art competency frameworks for the changing and specific needs of the Netherlands high-tech equipment industries.

The state-of-the-art assessment was based on a comprehensive review of the literature and web resources, both for the existing competency frameworks for System Engineering and common identified trends affecting the high-tech equipment industry. At the same time, insights into the state-of-the-practice were obtained through the consolidated experience of TNO-ESI with its Industrial and Academic Partner network and interviews and workshops involving representatives from Vanderlande Industries for the following roles: Platform Architect, Solution Architect, System/Module Architect, System Integrator, Systems Integration Manager. This was followed by a trial application and validation of the resulting updated framework for the selected roles in the industry use case of Vanderlande Industries. This document does not aim to be exhaustive nor complete. Its purpose is to initiate expertise building on the changes in the engineering landscape in the next 5 years and discuss how those changes will impact the required competences for System Engineering in complex system design and industrial environments.

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1 Introduction

The R&D of the high-tech (HT) equipment industry is in a series of transitions towards a more and more agile way of systems engineering, often in combination with the development of software-intensive systems. Transitions include moving from equipment engineering to developing and delivering solutions and services, from *engineering to order* to *configure to order* practices, towards model-based engineering methodologies and platform-based engineering. As the R&D and engineering landscape changes, the role of key system engineering stakeholders, such as architects and integrators, needs to change accordingly, which requires an updated skill and competency set.

The research aimed to expand, update and tailor current State of the Art competency frameworks according to the required future system engineering competencies for the changing and specific needs of the Dutch high-tech equipment industries, by trying to answer the below research questions:

RQ1. What is the set of Systems Engineering (SE) / Systems Architecting (SA) competencies that is required by the high-tech equipment industry in the Netherlands in the near future to develop and deliver solutions and services in configure to order, model and platform-based approaches?

RQ2. What are the future architecting challenges in view of the transitions in the industry and what are the consequences for the future architecting competencies? What are the consequences for existing R&D-teams?

RQ3. What is the distinction between the roles of System Engineers (SEs) and System Architects (SAs) in the Netherlands high-tech eco-system versus for instance the international INCOSE definition or common practice in the USA?

The report is organized as follows, chapter 2 discusses the approach to the research, chapter 3 shows the results, insights and observations, and in chapter 4 we make conclusions and propose next steps.

In the Appendices we show

- The job descriptions
- Competency model
- Mapping of posts to roles

The result of the review and update of the INCOSE competence framework is available as a separate MS Excel file [1] that should be read in conjunction with this report.

2 Research approach

In view of context and research questions, the following approach was defined:

- **Selecting a competency framework for systems engineering and evaluating its applicability to the broader high-tech industry in the Netherlands, validated in a case study at Vanderlande Industries.**
 - Literature review on current state-of-the-art competency frameworks for SE.
 - Interviews and workshops to understand the target group and calibrate the framework to five specific roles at Vanderlande.
 - Interviews and workshops to benchmark it with *Canon Production Printing and Thales Netherlands*.
- **Defining a high-level overview of the changes in “systems engineering/architecting of high-tech equipment in the near future” (5 years).**
 - Literature review on common trends for the industry.
 - Interviews and workshops to understand the expected impact of these trends in Vanderlande.
 - Workshop with Canon Production Printing and Thales Netherlands to explore how these trends are expected to impact them and what the consequences are for required competences of their systems engineers.
- **Updating and tailoring the selected competency framework to be fit for the coming 5 years.**
 - Interviews and workshops to understand the impact of the changes expected in the next five years in the competencies needed from SAs, SI and SI managers.
 - Joint review to fine tune the competencies descriptions and levels for the five selected roles at Vanderlande
 - Sharing of the findings and proposals with Canon Production Printing and Thales Netherlands.
- **Evaluating the INCOSE competency framework.**
 - Sharing the project findings and suggestions for improvement with INCOSE.

3 Results, insights and observations

3.1 Results

The process that we followed resulted in a structured method on how to tailor competency frameworks as described in the figure below (figure 1), here applied to the use case of Vanderlande. We started by collecting input from Vanderlande on the structure of the organization and the five roles selected as use cases (1), reviewing state-of-the-art competence frameworks for Systems Engineering and selecting the one that would best fit our needs (2), converting that framework into a survey to be used in the calibration interviews with representatives of each of the roles (3), a joint review of the levels needed for each competence for the five roles with the steering team from Vanderlande (4), the analysis of expected changes of the next five years and how those might impact Vanderlande and the competences for each of the five roles, resulting in a consolidated overview of competence profiles for these roles (5) and finally the benchmarking activities to assess how recognizable were these results for other partners representatives from Canon and Thales (6).

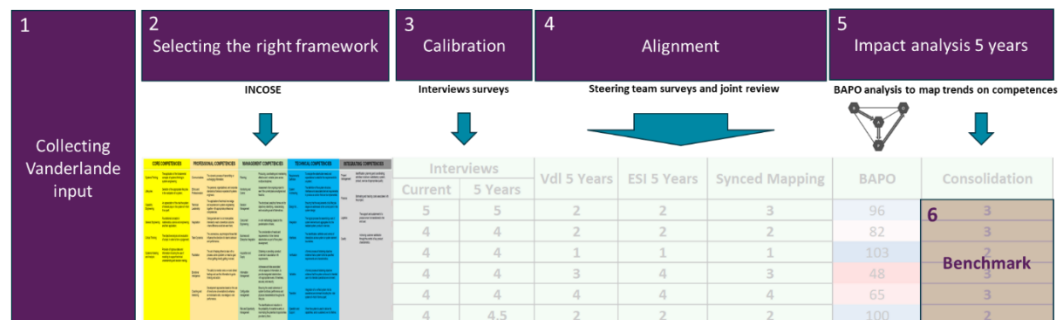


Figure 1 – Process that was followed.

Another result from this process was an updated competency framework with increased usability for diverse professionals in the Dutch high-tech equipment industries, taking into consideration the impact of generic trends in the next 5 years. This can be found in the accompanying Excel document [1], last updated on January 15th of 2025.

3.2 Insights

In this section, we describe the main findings of the process steps established for this project and share our insights and observations from the activities that took place.

Selecting a competency framework for systems engineering and evaluating its applicability to the broader high-tech industry in the Netherlands, validated in a case study at Vanderlande Industries.

Within the available Systems Engineering competency frameworks, there were two main frameworks that we considered for this project, one from SERC, resulting from the Helix research study [2] to identify the critical proficiencies needed by systems engineers and one from INCOSE [3]. We found INCOSE to be more aligned with the goal of the project for the international recognition within an active Systems Engineering community that can keep it alive.

Other generic benefits of the INCOSE framework are:

- **Structured Approach:** It provides a well-defined set of 36 competencies organized in 5 different competence groups encompassing the knowledge, skills, abilities, and behaviours critical for effective systems engineering, quickly identifying strengths and weaknesses in individual and team skillsets, by rating them in 5 different levels (awareness, supervised practitioner, practitioner, lead practitioner, and expert).
- **Tailorable Framework:** The framework is not a rigid one-size-fits-all approach. It is designed to be adaptable to specific needs. It can therefore be easily used as a foundation to create customized competency models that align with their unique projects and systems.
- **Improved Practice:** by identifying and addressing competency gaps, the framework can lead to overall better systems engineering practices within an organization which contributes to smoother project execution and more successful system development.
- **Career Development:** individuals can leverage the framework to identify areas for personal growth and development. It helps them tailor their learning and experience to target specific career paths within systems engineering.
- **Benchmarking and Accreditation:** the framework can be used as a benchmark to assess the effectiveness of systems engineering education programs or to establish competency requirements for specific roles within an organization.

In order to evaluate the INCOSE Competency Frameworks applicability to Vanderlande Industries, five roles were selected within Vanderlande Industries on which information was collected by reading job descriptions and understanding better how to map them in the organization:

- The Solution Architect;
- The Platform Architect;
- The System/Module Architect;
- The Integration Manager;
- The Integration Engineer.

A comprehensive description of these jobs can be found in Appendix 1.

To be able to calibrate the framework, we interviewed two representatives of each role, asking them to fill out upfront a self-assessment based on the competencies featured in the framework to get them familiarized with it. Through these interviews, we got important insights on what each role means in terms of day-to-day activities and how these fit in the organization. We also got the chance to discuss their view on the framework and concluded unanimously that it was well suited for their reality, since no competences were found redundant or missing.

We asked the same from a total of ten representatives of two other partners, Canon and Thales, and the conclusions regarding the suitability of the framework were similar for system architects in general in these two organizations.

Defining a high-level overview of the changes in “systems engineering/architecting of high-tech equipment in the near future” (5 years).

To ensure that the research of ESI is relevant for the Dutch high-tech equipment industry, we regularly conduct a process to take stock of the needs of the industry. In December 2022 we published an article in the Insights issue of the Archimedes initiative [4]. In this article, we explained how we mapped the business, and capability needs to the area of (systems) engineering, summarizing the following critical trends that follow from that to assess complexity growth associated with the widespread digital transformation:

- enhanced criticality and diversity of systems;
- continuous innovation and updating with a more agile system engineering method;
- the climb of equipment manufacturers in the value chain and broadening the scope of their activities;
- the high demand for engineering experts and the need to maximize productivity and quality, calling for the “democratization” of the system engineering and of research and development R&D.

From the review of other articles, more directly related to what is expected from the future workforce [5], [6], we confirmed that these trends are still valid, adding to them the anticipation of a work environment geographically dispersed, culturally diverse, gender agnostic, multi-disciplinary and trans-generational, and with an emphasis on industry collaboration to what concerns the business environment, in the face of competition.

Based on these generic trends, we asked Vanderlande to discuss internally what changes they expect, within the business, the architecting, the processes and the organization, using the BAPO framework [7] to reason about the relations between them.

The following changes were recognized by Vanderlande:

- the transition from a project to a product-based company, with customizable platform-based design with independent modularization;
- seamlessly integrating third party solutions to co-create and provide lifecycle software intensive solutions with continuous upgrades and updates;
- everything is digital and automation and modelling are default to provide automated digital service solutions, where cybersecurity is critical;
- scarcity of resources and the growing role of AI taking over ‘many’ of today's human tasks in development, customer project delivery and customer life cycle solutions
- global growth as a driver to share teams and working remotely and with diverse cultures;
- internal processes focussing on speed of decision making based on DATA and with fast feedback loops over the complete lifecycle in an agile way of working.

The other companies entirely recognized the same generic trends posteriorly, although with different ways of addressing them within their organizations.

Updating and tailoring the selected competency framework to be fit for the coming five years.

After concluding the framework was well suited for the current System Engineering needs and aligning on industry trends and their impact on Vanderlande, we analysed the fit of the framework for the future competence needs of SEs.

We reviewed each competency description and adjusted it where appropriate. Main changes were:

- Translating them into a more accessible language to make it more comprehensible

- for technical and non-technical professionals;
- Referring to teams as being more diverse and multi-disciplinary and how that can impact an effective communication and knowledge transfer across domains (need to understand and appreciate diverse cultural values, beliefs, and communication styles and to avoid the tendency to view everything through the lens of each own beliefs);
- Reinforcing the need for a faster update of knowledge and a responsible use of emerging new technologies assessing its credibility to support informed decisions even with limited data.
- Adding sustainability as a system quality that should be accounted for from the design phase;
- Making more explicit in the requirements definition that one should analyse all stakeholder needs and expectations to establish the requirements for the system and its full life cycle (customer, supplier, external) and the importance of understanding the value chain and ones' position in it.

From the need for the agility required to respond to the fast-evolving environment of the industry, we added a new competence, the "Openness to Change" as in "the receptiveness to the unfamiliar while taking ownership of your own development to make sure you are up-to-date and fit for what is coming". Although implicit in other competencies, we believed the impact of this need was significant to what concerns the professional competencies required for future systems engineering and decided to add it more explicitly in the framework, also defining indicators of knowledge and behaviour for each level, as per the table below. This was confirmed when applying the updated version of the framework to the integrators role that rated it with at least the need of a practitioner level.

COMPETENCY AREA - PROFESSIONAL: OPENNESS TO CHANGE				
Description: The ability to embrace and approach unfamiliar situations with curiosity, while taking ownership of your own development addressing challenges as opportunities, feeling comfortable with trial and error and being open to feedback.				
Practical Meaning: In practice it's about quickly adapting and adopting changes, by being aware of the need for change and how to implement it and being willing and able to do it and sustain it.				
EFFECTIVE INDICATORS OF KNOWLEDGE AND EXPERIENCE				
AWARENESS	SUPERVISED PRACTITIONER	PRACTITIONER	LEAD PRACTITIONER	EXPERT
Shows awareness and acceptance of the need for change.	Expresses willingness to participate and support the change.	Has knowledge on what is needed to implement the change.	Is able to implement desired skills and behaviors for the change in himself and others.	Sustains the change by reinforcing it throughout the organization and to the outside.
Inquires about the details of the change, its purpose, and potential impact, asking for clarification and seeking to understand the bigger picture.	Links the change to a bigger cooperate change program and shows how it contributes to this, knowing how to answer why the change, why now and how it impacts them.	Volunteers to be part of a pilot program or experiment with a new process.	Creates working group on the change within the bigger program to build awareness of the need for change within the organization.	Develops and transfers knowledge on how to change.
Recognizes negative outcomes that could have been prevented if the change had been made earlier.	Can highlight the potential upsides of the change and shows interest in learning more about the change and its benefits.	Demonstrates support for change in active and observable ways, by for example sharing personal impact messages with direct reports about the change via intranet, newsletters.	Proposes ways to improve the change process or implementation and creates targeted and customized tactics for managing the change and resistance to it as it occurs.	Proactively defines what kind of resistance can be expected in different contexts, the root causes of such resistance, and unique barriers to change.
Pays close attention to information about the change and are receptive to new ideas or perspectives.	Is open to trying different ways of doing things and seeing what works best in new contexts.	Actively seeks feedback on how they're handling the change and is willing to adjust their approach based on the input.	Coaches individual employees throughout the change, providing the necessary training, information and support they need to effectively adopt and use the change.	Sets up communities of practice around the change inside and outside of the organization to share information, lessons learned etc.

From the increasingly complex and dynamic environments, we also added another new professional competence, the "Personal Ownership", as in "the need of taking full responsibility for one's work and its outcomes, by anticipating issues and addressing them before they become problems, committing to complete tasks and projects and being dependable and consistent in delivering high quality results". Being proactive in identifying and solving problems, ensuring tasks are completed to the highest standard, and being accountable for both successes and failures was considered to be crucial and needed therefore to be added as a separate competence.

COMPETENCY AREA - PROFESSIONAL: PERSONAL OWNERSHIP				
Description:				
Taking full responsibility for one's work and its outcomes, by anticipating issues and addressing them before they become problems, committing to complete tasks and projects and being dependable and consistent in delivering high quality results.				
Practical Meaning:				
In practice it's about being proactive in identifying and solving problems, ensuring tasks are completed to the highest standard, and being accountable for both successes and failures.				
EFFECTIVE INDICATORS OF KNOWLEDGE AND EXPERIENCE				
AWARENESS	SUPERVISED PRACTITIONER	PRACTITIONER	LEAD PRACTITIONER	EXPERT
Recognizes the importance and understands the significance of personal ownership in achieving project goals.	Takes responsibility and completes assigned tasks reliably and on time, with supervision.	Manages workload by effectively prioritizing and managing own tasks to meet deadlines.	Leads by example, demonstrating a high level of commitment and responsibility, setting a standard for others.	Sets strategic direction for projects, ensuring alignment with organizational goals.
Seeks guidance by regularly asking for help and feedback from more experienced colleagues and actively listening to feedback with willingness to improve.	Regularly seeks and acts on feedback to improve performance and reflects on errors and takes steps to avoid repeating them.	Shows accountability for both successes and failures, learning from each experience.	Provides guidance and support to junior team members, encouraging their development and ensuring that team efforts are aligned with organizational goals and standards.	Recognized as a thought leader in this field, contributing to regional, national or international best practices and standards, mentoring other professionals and fostering a culture of personal ownership and accountability within and outside their organization.
Shows initiative by occasionally suggesting small improvements or new ideas.	Demonstrates initiative by suggesting minor improvements to processes.	Proactively identifies potential issues and takes steps to mitigate them and improve work processes and efficiency.	Leads initiatives and implements improvements to processes and practices based on past experiences.	Continuously seeks innovative solutions to complex problems in the field of systems engineering beyond the organization.

Concrete examples from Vanderlande of how an analysis can be made on the impact of a change on the required competency scope per role and the desired competences of persons within an organization:

Example 1: Systems become larger and complex in a world of fast evolving technology, with less resources and where co-creation and integration with partners is required to create updated solutions and to make speed.

Change - Architects need to be able to deal with more uncertainty and rely on digital modelling techniques to manage architecture & design complexity; Integrators are confronted with automated testing based on descriptive models provided by the architects. Both architects and integrators need a learning mindset to stay up to date with state-of-the-art available technologies and understand team dynamics to build the right team for the job. Creating trust between architects and integrators is key for success, which means involvement of both roles in all stages of the system lifecycle is needed.

Competencies – significant increase in systems modelling and analysis competencies. The architect plays a key role in creating the descriptive models (for concept, solution, and instance) and the integrator in creating the analytical models (for (early) verification and validation). Technical leadership and team dynamics will become more important. Especially the on-site integration team can be confronted with scarce resources and cultural aspects due to the global scale on which Vanderlande carries out its projects. The team heavily depends on the quality provided by the factory. Integration & interfaces require more attention, because platform architects and integrators need to consider multiple solutions of which Vanderlande products will be part of. This has consequences for decision management and risk and opportunity assessment. Platform architects and integrators need to decide whether to go for standardized (platform) or customized solutions, where integration managers have a key role in assessing the risk of standardized versus customized solutions.

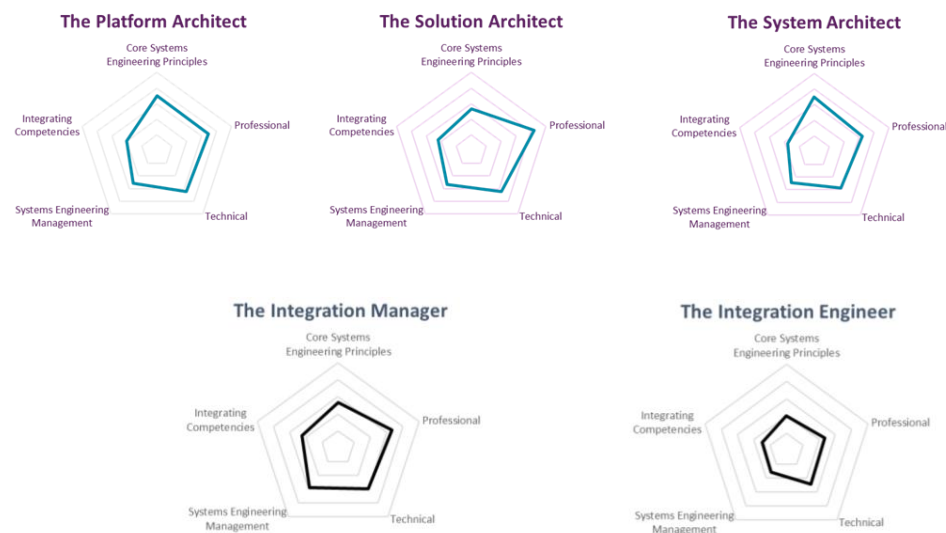
Example 2: Sell a service instead of a product.

Change – Architects need to consider lifecycles of individual modules and to include upgradeability/evolution of customer systems in the design from the start, define strategy & enablers to verify quality of upgrade paths, maintain configuration of different (to be) supported versions in the field, include evolution and update needs in the customer solution design processes and understand related business models.

Competencies – significant increase in the selection of appropriate lifecycles in the realization of a system (Lifecycles Core Systems Engineering Principles competence).

Architects need to consider not only the basic operational use cases but also support related ones for future upgrades and modifications. Integrators and solution architects are ‘closer to the fire’ and more aware of the operational context of solutions. They can provide insights and operational constraints based on their domain knowledge about operation and support. This change also requires increased proficiency levels for information and configuration management competencies for the integrators - understanding which release of which module is part of which solution and (shared) part of which platform, including the understanding of possible and actual configurations.

Regarding all applicable competencies (the ones provided by the INCOSE framework, and the ones specifically added), the impact of each change as per the examples above was included in determining the required proficiency level for each of the five senior roles. Result of the analysis is visualized in a collection of spider graphs for each role that shows the required profile per competency area (a cluster of competencies) and per competency of a competency area.



Considering the competency areas per role, core systems engineering principles and technical area are key for architect roles, where each role focuses on a different system of interest (and therefore has another lifecycle to consider). For the integration manager, systems engineering management is a key competence group and the technical area was found to be key for the integration engineer. Both architect and integrator roles highly depend on each other.

To validate the findings at Vanderlande, two separate benchmark sessions were organized with comparable high-tech companies active in the high-tech Cyber-physical domain, Canon and Thales.

The benchmark confirmed the applicability of the framework. Some calibration along the levels was required since the required levels for a specific role are dependent on the organizational structure [8]. Role descriptions are company-specific, which complicates direct benchmarking.

The companies that participated in the benchmark, and Vanderlande industries, are all in a multi-dimensional transition in which all elements of the BAPO framework are changing. By focusing on competencies, you create a joint and concrete starting point for discussion and reflection between different organizations. However, as all BAPO-elements are connected, it became clear that developing SE competencies in a changing business-context requires a broader approach than “just” focusing on SE competencies of individuals and teams. A more

strategic alignment of Business, Architecture, Processes, and Organization is needed. In short, SE competence development is a strategic activity and needs to be coordinated, especially in times of change.

Evaluating the INCOSE competency framework.

Competencies are considered to be one of the systems engineering challenges [5]. In an online session with the development team of the INCOSE competency framework, the project results were shared and discussed. The development team shared their ideas on governance and management of this framework and it was agreed that a follow up would take place in the planned 2025 INCOSE International workshop.

3.3 Observations

One important achievement from the steering team working on this project in Vanderlande was reaching a common language within the Architects and the Integrators team, but also between them. The joint review and update of the framework triggered important conversations and allowed them to build a common understanding of what should be critical competencies for each of these roles, connecting the systems knowledge of architects, the more risk and process-oriented knowledge of integrators as well as other roles within Systems Engineering.

Another observation is related to the importance of governance and management of competencies for the development of SE capabilities of an organization. The project results were shared with INCOSE that showed interest in using our insights to further develop the framework (by adding competencies or adjusting their description) and translate it into a usable tool by organizations (for which our use cases could provide crucial input). INCOSE is working on an updated version of the framework, and a model-based competency assessment approach, which was shared during the International Symposium in 2024 [9]. This transition from a document- towards a model-based approach, ensuring proper governance and management of the information shared by INCOSE is now their priority, for which the work in progress described in Appendix 2 can be a contribution.

The last observation relates to the distinction between Systems Engineering Roles versus Systems Engineers' Roles. Due to scarcity in resources within organizations, it might need more individuals to successfully play a systems engineering role like an architect or integrator. The *Twelve Systems Engineering Roles* [10] considers these 'team roles' and is currently being updated towards nine primary and eight supporting systems engineering roles. This update can provide a good starting point for defining the required roles and posts for the future workforce and developing organizational/team capabilities and individual competencies. In Appendix 3, a mapping is proposed between posts and roles and individual versus team roles.

4 Conclusions and Next Steps

4.1 Conclusions

Considering the initial research questions and the designed process (or methodology), three main generic conclusions can be drawn from the ArchSkills project:

RQ1. The INCOSE Systems Engineering Competency Framework [3] provides a very practical structure and library of competencies for every role a systems engineer within an organization can play. However, further explanations or adjustments of the descriptions per competency and why they matter are needed to fully understand the meaning within the context of the business.

RQ2. The method developed in this project provides an effective way to select, complete and tailor frameworks for a specific business-line or organization. It has now been done for five SE roles but can be repeated for other roles as well. Other frameworks may be selected as a starting point (for example for Project Management Roles which partly overlap with Systems Engineering Roles). Based on business trends and drivers, the scoped competences will need regular updates, so governance and management are important to consider.

RQ3. There is no distinction between the INCOSE Systems Engineering Roles and the Dutch high-tech System Architect and Integrator Roles, to what concerns the applicability of the framework. The framework from INCOSE was recognized by Vanderlande and in the benchmark activities as valid for their organizations. The levels needed for each competence will have differences, but the scope of competences needed for SE in general is the same.

4.2 Recommendations and next steps

The following recommendations for the Systems Engineering competencies of the Dutch high-tech equipment industries can be drawn from the ArchSkills project which can lead to needed follow up steps or open topics for future research:

1) Do not reinvent the wheel and use wisely what is out there

For each role, the competence scope for a senior employee was defined; meaning junior and medior employees might need to develop their competencies to acquire the appropriate proficiency level. Using the INCOSE framework for the Vanderlande organization resulted in a validated overview of applicable competencies, scoped for five specific roles of a systems engineer, and fit for the next five years. These scoped competencies per role can then be completed for other roles as well and be used for multiple purposes, for which the framework provides the basic use cases, like making job descriptions, performing individual assessments to identify areas for personal growth and developing and tailoring learning programs [4]. Job descriptions (posts) will need alignment with the HR department and the Job Level Scale which will determine career progress and salary updates (rewarding an individual for filling in a post within the organization).

2) Stop looking for the unicorn and start collaborating as teams

It makes sense to decouple (systems engineering) processes from organizational structures by distinguishing roles from jobs (posts). An individual person can play a role in performing actual work (as part of the process) and can fill a post as part of an organizational structure [2,7]. Looking at the trends in the industry, there is an increased need for more generalist *and* specialist roles, to the extent that no individual person can play this role alone anymore. However, there is also the challenge of scarcity in resources, so we must consider ‘team roles,’ where a group of people will play the role of architect or integrator (see Appendix 3).

3) Start developing team capabilities as well as individual competencies.

Based on the need described above to change the narrative of developing needed individual competences of “local heroes” to needed capabilities of an SE team that can cover all competency groups, learning programs should also focus on team capabilities and not only on individual competences. Key competencies per role are more relevant when preparing a training for a specific role, but when preparing a training for a team role it might be more interesting to focus on differences between the individual roles and responsibilities involved. Although we presented results in the form of spider graphs for five specific roles of a systems engineer, other ways of representing the data might be more appropriate when a clearer purpose is defined (see appendix 2).

5 References

- [1] J. Teixeira, B. van der Leeuw, B. Pronk, P. Goosen and T. Hendriks, “ArchSkills SE competency framework,” TNO R2025-1001, 2025.
- [2] N. A. C. Hutchinson, D. Verma, P. Burke, R. Giffin, S. Luna, D. Makwana, S. Kothari, B. Salgado, H. Y. See Tao and S. Soneji, “Helix: Developing an Understanding of Organizational Systems Engineering Effectiveness,” 2019.
- [3] INCOSE, “INCOSE systems engineering competency framework,” INCOSE.
- [4] W. Leibbrandt, J. Wesselius and F. Beenker, “TNO-ESI – Systems Engineering Methodologies for Managing Complexity in the High-Tech Equipment Industry: Our Roadmap,” *INSIGHT*, vol. 25, no. 4, pp. 15-21, December 2022.
- [5] INCOSE, “Systems Engineering Vision 2035,” INCOSE, 2021.
- [6] H. Stoewer and D. Nichols, “Building the Systems Engineering Workforce of the Future,” INCOSE, 2022.
- [7] J. Bosch, F. van der Linden, E. Kamsties, K. Känsälä and H. Obbink, “Software Product Family Evaluation,” *Lecture Notes in Computer Science*, vol. 3154, pp. 343-357, 2004.
- [8] R. Beasley, “The need to tailor competency models- with a use case from Rolls- Royce,” INCOSE, 2013.
- [9] J. Amenabar and C. Whitcomb, “INCOSE Systems Engineering Competency Assessment Guide Systems Modelling Language (SysML),” INCOSE, 2024.
- [10] S. Sheard, “Twelve Systems Engineering Roles,” INCOSE, 1996.

Appendix 1

JOB DESCRIPTIONS VANDERLANDE

The Solution Architect is a technical lead for the solution at the customer site. Solution Architect has a strong focus on the deployment of systems. He should have a very good understanding of the domain and context for specific deployment projects. This relates to interactions with operators and users (operational scenario's) and interactions with the implemented (enabling) technology.

The Platform Architect is a technical lead on system level developments. Platform architect is a real system thinker, able to interact with cross functional stakeholders in both the development and customer project execution value chain. They have a decent understanding of business impact on system and solution level and translate this into requirements, architecture, and design of solutions. This includes both functional and non-functional aspects. Platform architects are involved in the whole development cycle, typically leading the first phases of system level solution or larger module initiatives, managed in business portfolio teams. Main activities here are requirements analysis and solution design creation that result in clear input for development teams to develop the solutions.

System or solution level development can only be successful when executed in a team effort. Collaboration with customer project teams, product management and development teams are daily practice for a platform architect.

The System/Module Architect is a technical lead for the subsystems or modules that together provide the system level capabilities and customer solution services. System Architect is both involved in the development and customization of modules. Focus is on standardization, commonalities, and reuse of existing modules, which requires interaction with the platform architect. He should therefore be able to distinguish both system lifecycles and be able to justify the feasibility of new/upgraded modules for implementation.

The Integration Manager is overseeing continuous integration of solutions from multiple departments and is responsible for delivering high quality integrated solutions. The Integration Manager makes the integration planning, coordinates between different teams/departments to plan, execute, and maintain integrations, troubleshooting any issues that arise during the process. Their goal is to ensure that the right quality insights are provided for the solutions delivered to the customers in alignment with business requirements and time schedule.

The Integration Engineer ensures that various systems and components work together as intended. This involves designing, implementing, and managing tests to verify the functionality, performance, and reliability of integrated systems.

Appendix 2

Purpose of the competency model

All models should have a purpose. A competency model might be useful in supporting multiple goals like shown in Figure: 2. With the capability of 'scoping competencies per (individual) role', the assessment of personal profiles within an organization is possible. These scoping and assessment results might even enable the (continuous) development of organizational capabilities.

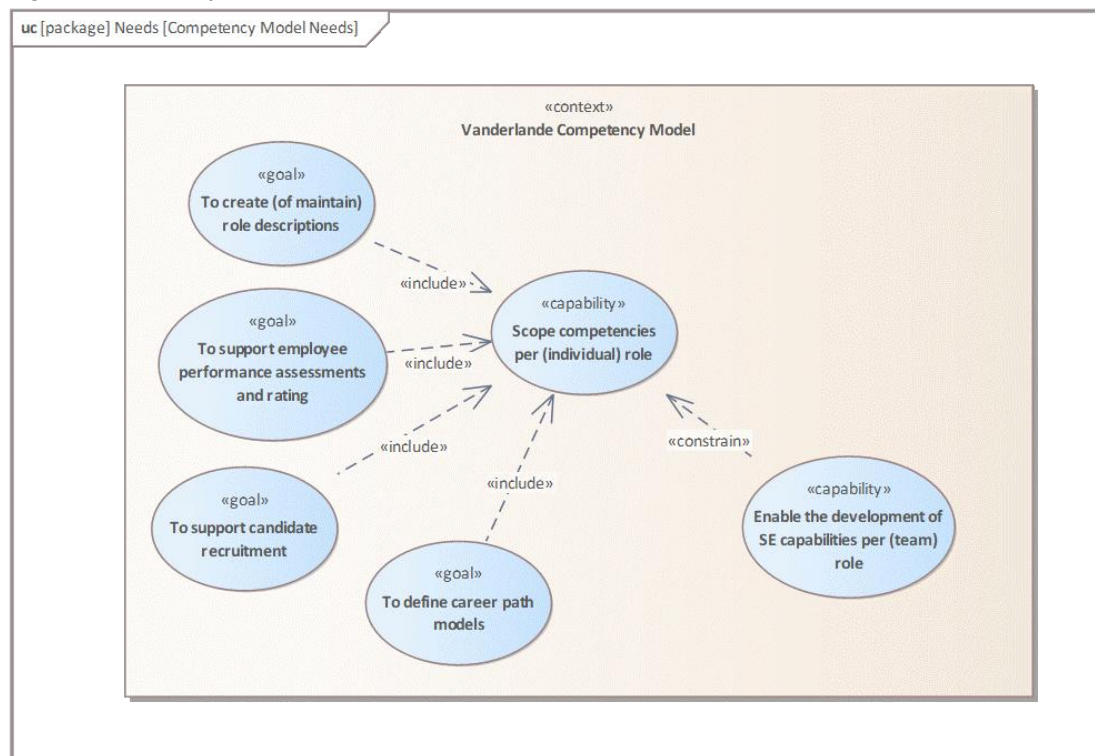


Figure: 2 Competency Model Needs

Note: The development of SE capabilities of an organization might relate to the organization as a whole, organizational units or project teams.

Key concepts and principles

Before creating a competency model, it is good practice to first define the key concepts and principles to explain the meaning of model elements. Figure: 3 illustrates what we mean with a competence in relation to a stakeholder role (that is responsible for project/process related activities) and a post within an organization.

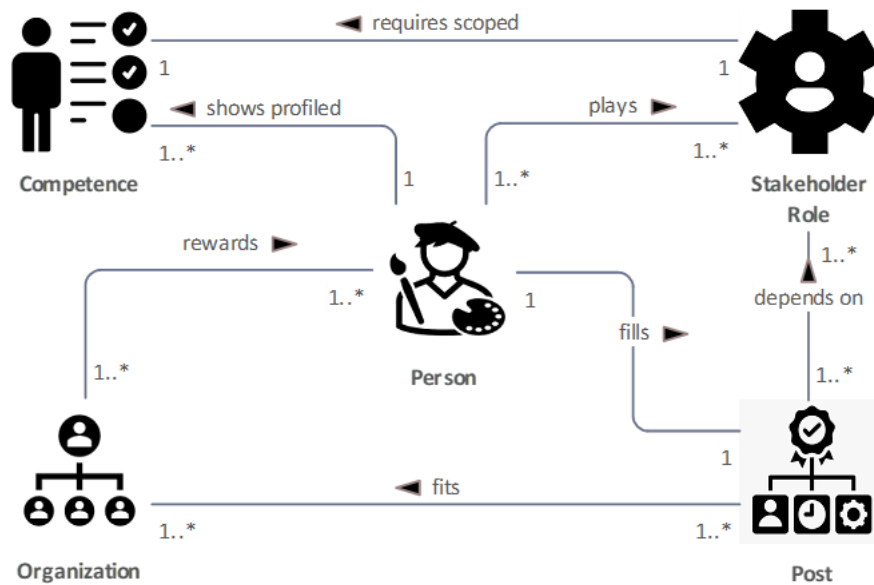


Figure: 3 Competency model elements

Note: A competence scope consists of the required competencies per role and a competence profile shows how well an individual person that fills a post covers this scope (e.g. fully, partially, or non-compliant).

Vanderlande competency model organization

In the ArchSkills project, an example of a competency model is made, for a selection of five stakeholder roles that relate to individual posts within the Vanderlande organization. The figure below shows how the competency model is organized.

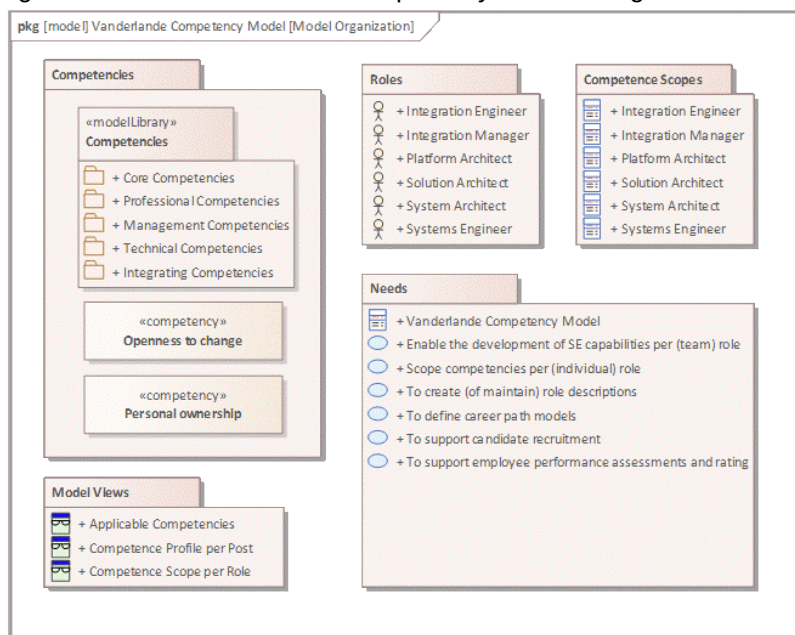


Figure: 4 Model Organization

Note: The INCOSE Systems Engineering Competencies [2] are imported as a Model Library to the Vanderlande Competency Model. The descriptions of these competencies are modified and equipped with a further explanation to speak the 'Vanderlande language'.

Selected stakeholder roles

In the ArchSkills project, a total of five individual roles/posts were discussed, related to architecting and integrating activities. Therefore, this example of a competency model does not cover all systems engineering activities and life cycle processes.

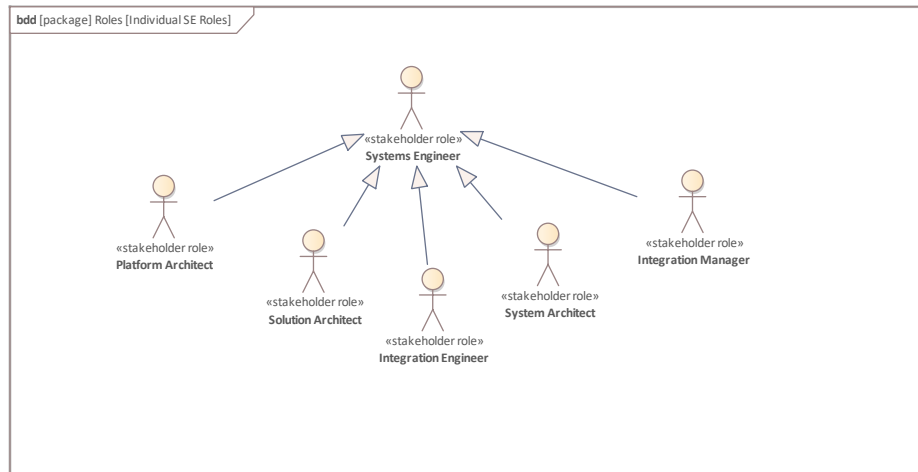


Figure: 5 Individual SE Roles

Applicable systems engineering competencies.

In the ArchSkills project, two competencies needed to be added to the ones from the Model Library. Openness to change and Personal Ownership were considered essential competencies required by all five stakeholder roles. Also, no competencies could be left out of the Model Library, meaning all of them were considered relevant.

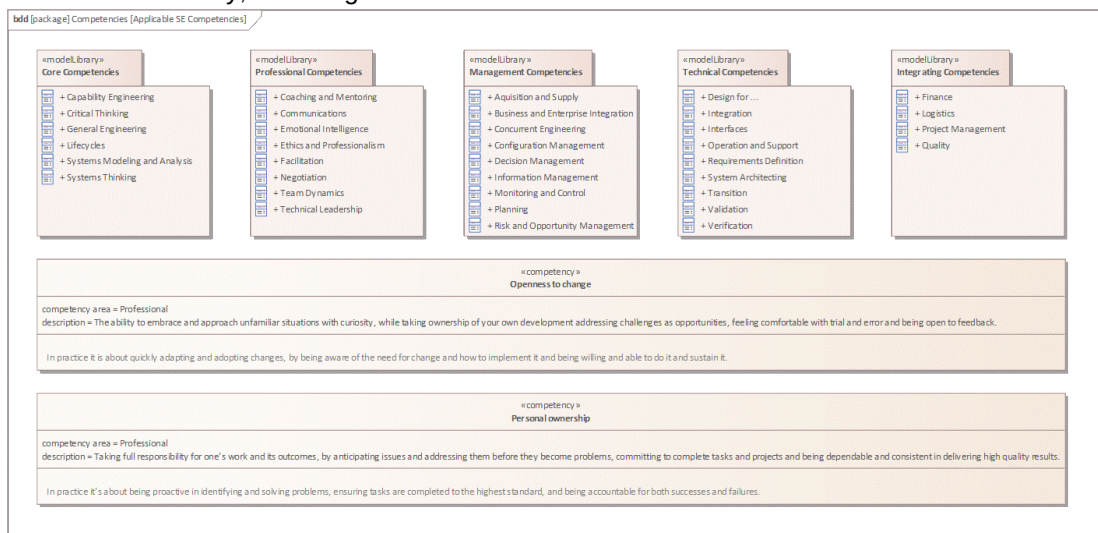


Figure: 6 Applicable SE Competencies

Competence scopes per role

After identifying all applicable systems engineering competencies per role, scoping the proficiency levels per competency can be done by adding initial values. The figure below shows the competence scopes of both a senior integration manager and senior integration engineer.

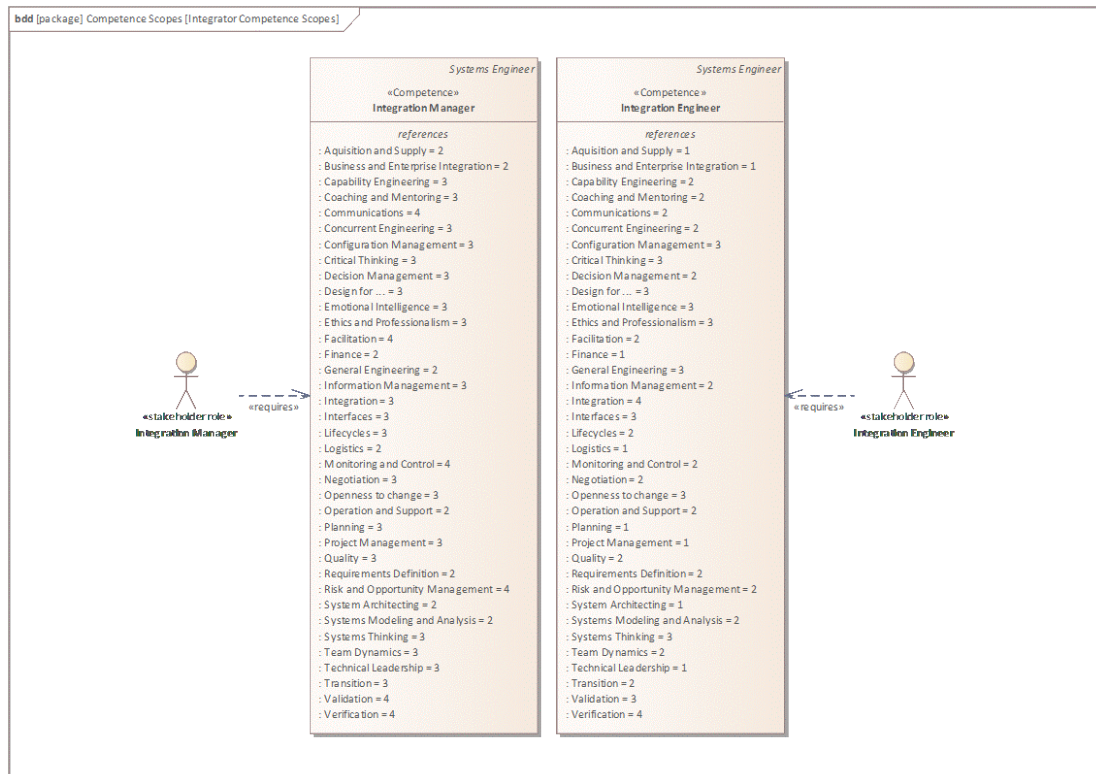


Figure 7 Integrator Competence Scopes

Note: Numbers in this figure might not be updated and are just used as an example.

Model views - TO BE DEVELOPED

Depending on the purpose of the model, different model views might be relevant (see also Figure 9). For example, the human resources manager would like to see other information than the project manager that needs to staff his project or a change manager that wants to develop new organizational capabilities.

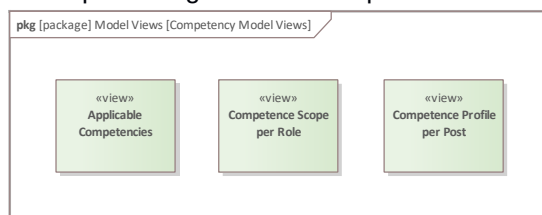


Figure: 8 Competency Model Views

Appendix 3

Mapping of Posts to Roles

Roles are defined to allocate responsibilities over different activities. These responsibilities can be related to an individual or a team. Systems engineering is considered to be a team effort, where collaboration is key. There is never one person capable of covering all bases. And the more complex systems are becoming, the more interaction might be needed, where organizations can be structured in such a way, they support collaboration. Depending on the type of organization, this can be anything from a very hierarchical to a very informal structure.

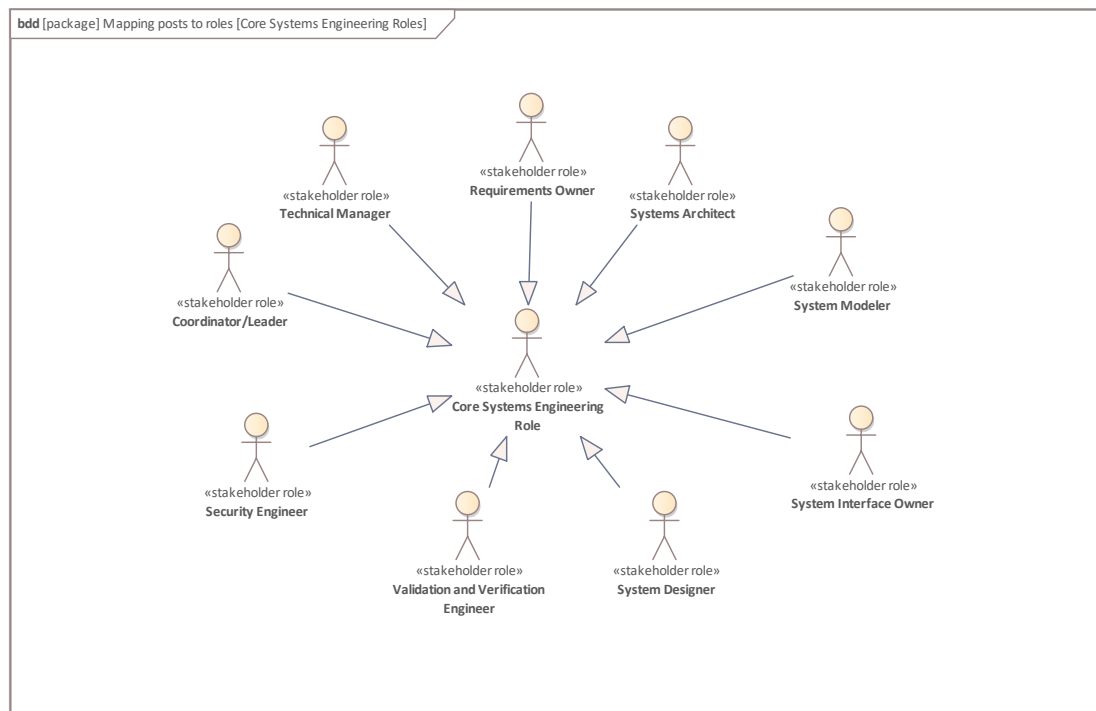


Figure 9 Core systems Engineering Roles

Research is being done to continuously keep track of the systems engineering roles. Initially twelve (team) roles were identified [10], which now evolved towards seventeen roles. Nine of these roles are core and eight are enabling. Figure 10 displays the core systems engineering roles suggested by Sarah Sheard in 2024, [A chat with Sarah Sheard, recorded December 14, 2023](#)].

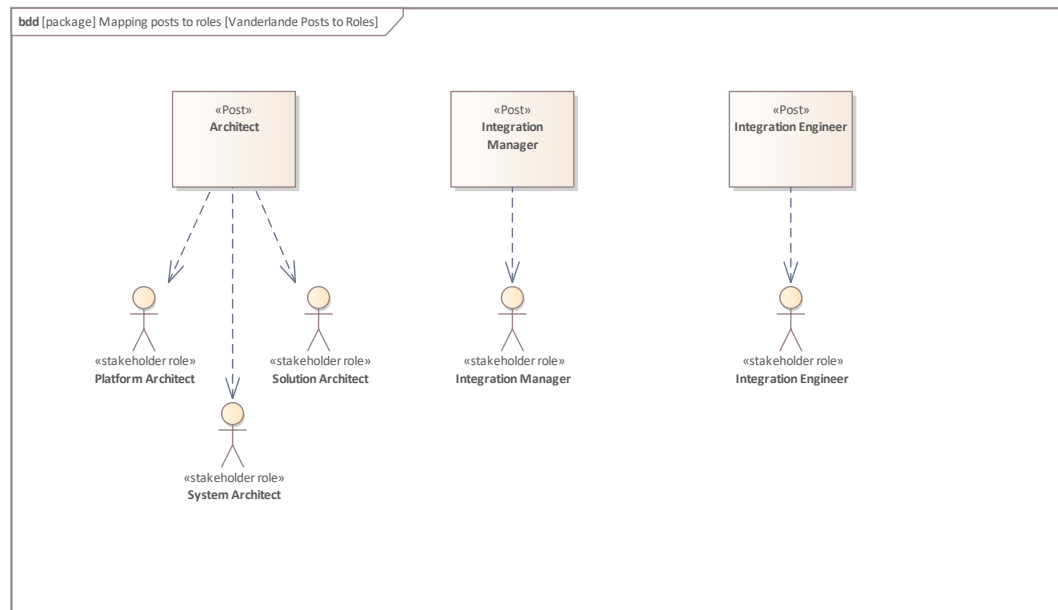


Figure 10 Vanderlande possible mapping of posts to roles

In the ArchSkills project, initially no distinction was made between roles and posts [refer to Appendix 1]. The project considered five roles, each of them with another system of interest and therefore lifecycle to consider. At Vanderlande System Architects are specialized towards a specific system of interest (solution, platform or system/module) and therefore consider different lifecycles while System Integrators are specialized towards Technical Manager and V&V Engineer roles.

The distinction between INCOSE Systems Engineering Roles versus Dutch high-tech System Architect and Integrator Roles is that the INCOSE roles are process-based and can be played by a team, while Dutch approach is more human-centric and based on individual responsibilities and flat organizations and therefore roles are considered to be individual jobs.

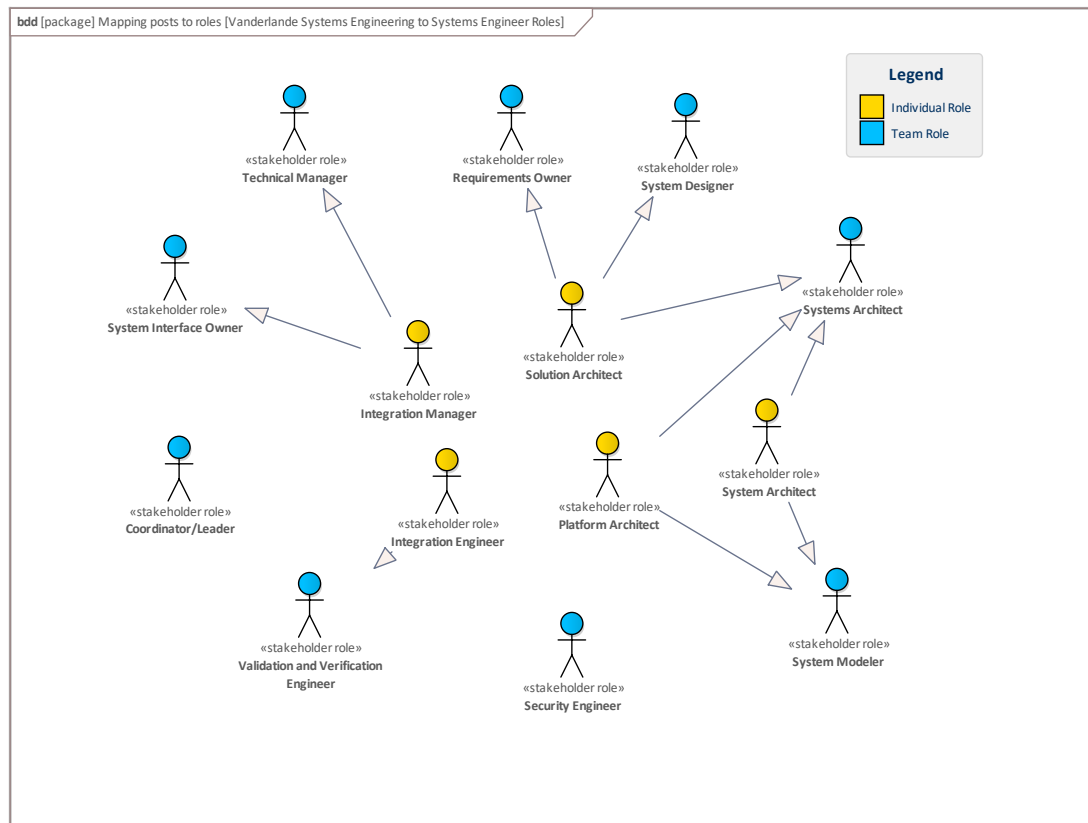


Figure 11 INCOSE Systems Engineering to Vanderlande Systems Engineering Roles

Figure 11 shows a plausible mapping of the individual towards team roles from Figure 9 and Figure 10. It confirms that not all systems engineering roles are scoped yet in Appendix 1. Clarity might be needed on which individual roles are related to the Coordinator/Leader and the Security Engineer.

ICT, Strategy & Policy

High Tech Campus 25
5656 AE Eindhoven
www.tno.nl