Competence development of System Architects.

White Paper Resulting from Architecture Forum Meeting

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1. Introduction

Many companies are experiencing a severe shortage of system architects. The system architects that are available often emerge after working for decades in an organization. The growing complexity of systems, the increase in size of development organizations, and the increasing amount of interaction and integration with the surroundings all increase the need for architects. At the same time it is observed that increase of organization size often results in specialization, rather than growing generalists like system architects.

Many initiatives are emerging to tackle the shortage of system architects more pro-actively by creating competence development programs. This forum discussed the following questions:

- How to develop System Architecting Competence?
- How to educate System Architects?
- How to find / select potential System Architects?
- How to educate, train, and instruct management in dealing with System Architects?

The participants of the architecting forum are either active as provider (university or institute) or they are at the receiving side, working in companies and are faced with the challenge of internally developing architects. We had 6 organizations attending the meeting with experience in the field of system architecting competence development. The three provider organizations are:

- Stevens Institute of Technology, Hoboken, NJ, USA
- Embedded Systems Institute, Eindhoven, The Netherlands
- Buskerud University College, Kongsberg, Norway

Practitioner organizations which have an active system architecting competence development effort are:

- Raytheon Company
- Philips Research
- Nokia

While it is not obvious from the list, there is also high interaction between the provider organizations and the practitioner companies, the boundary between provider and practitioner is much less sharp. Providers rely heavily on practitioners as a source of teachers and cases, and the companies base their programs partially on provider offerings.

Nokia Siemens Networks is also active in competence development, but the participants that were present are not directly involved in this program and therefore were not able to speak to the details of the program. For that reason we did not include the Nokia Siemens Networks experiences in this paper.

Interesting, observable differences in approach between the discussed competence development programs included:

- the ratio between courses (lecturing) and practice (projects, on the job training and coaching)
- the duration of the program
- prescribed curriculum versus menu-based
- formal accreditation versus informal certification
- early strong selection versus little or no selection up front

2. Organizational versus personal competence development.

Today's increasing expectations of products, increasing complexity, integration, and interoperability, shortened development cycles and large distributed development teams require many organizational competences such as marketing, project management and systems architecting. In these circumstances a company needs organizations that have the

competencies listed above. Part of the organizational competence is staff with system architecting competence. However, the presence of competent system architects in the organization is not sufficient to state that an organization is effective in systems architecting.

Principle 7.1 An organization that is competent in systems architecting needs more than competent system architects*. The organization also needs a shared vision on architecting, managers and engineers that are architecting aware, and support for architecting such as processes, tools, and an organizational infrastructure.*

What was discovered through discussion is that there is clear tension between the long term need for competence development and the short term financial pressure. Organizational competence is required to provide appropriate support for competence development of individuals. There is a chicken and egg problem in raising the organizational competence level.

Figure 1 shows a map of elements involved in the organizational competence of Systems Architecting, elaborating Principle 7.1. Systems architecting competence is one of the means to achieve the business strategy – it is necessary but not sufficient. A shared vision on architecting is required to be effective in systems architecting. The work of system architects and other employees, such as managers and engineers, should fit; educating the other employees in architecting helps to make the fit. The architects are embedded in an organizational infrastructure, for example with Architecture Review Boards (ARB), and supported by processes and standards. Further facilities might be tools, repositories and shared artifacts, e.g. reference architectures.

Competence development of individuals happens within the context of their organization. An unbalance between individual competence and organizational competence lowers the effectiveness of architecting. Most of our discussions in the forum have been focused on competence development of individuals. However, it is clear that competence development of the organization needs to take place concurrently. As an example, Raytheon has been

active both in organizational as well as in individual competence development for many years.

Figure 1, aligned with the business strategy, requires a shared vision on architecting, competences of the architecting staff, an organizational infrastructure, processes and standards, and facilities such as tools.

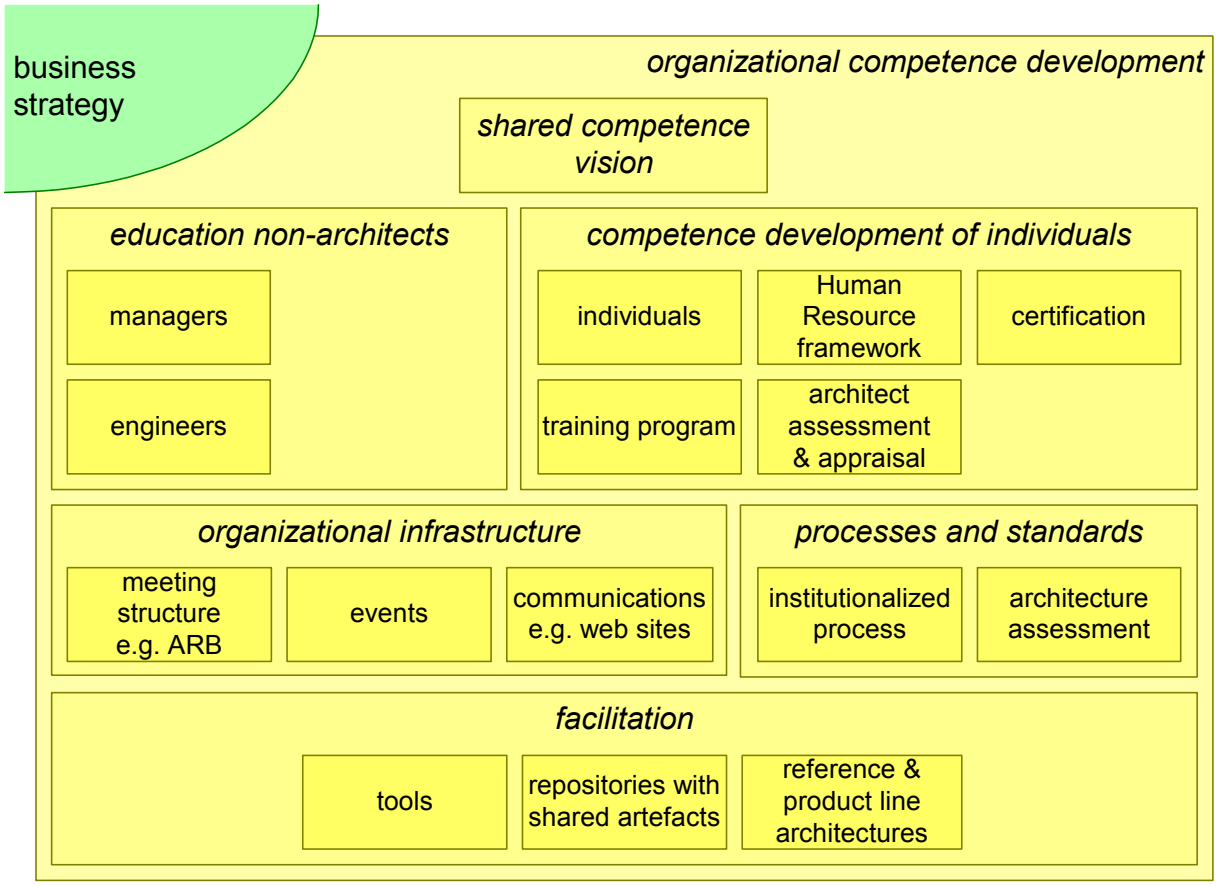

Figure 1: Organizational Competence

3. Needs for personal competence development program

During the forum meeting we conducted a brainstorming session regarding the needs for competence development. The result of the brainstorm provided a wide variation of subjects, ordered in the following subjects groups:

- **Goals** of the competence development
- **Skills** to be developed
- **Purchasing** requirements for the competence development elements
- **Context understanding** to be present in (future) system architects
- **Technical content** of the system architecting job
- Categories of **knowledge** that system architects must have in their position
- **Spin-off** of taking part in competence development programs

The complete brainstorm is shown in Figure 2. While a discussion of the complete brainstorm results is beyond the scope of this white paper, some of the more relevant observations are discussed in the following paragraphs.

First, when discussing the skill needs for competence development it became apparent the most dominant needs are the (soft) skills. Interestingly, least dominant is the need for technical content. In fact, we gathered the technical content explicitly at the end, because it was seen as hole in the inventory of needs in first instance. The archetype of the (potential) system architect seems to be the technically fluent person with less developed interpersonal skills. Within the forum, communication is perceived as one the major activities of an architect. Communication skills are also dominantly asked for. Related to the soft skills is the need to understand architecting in the broader context of the business and over the complete life cycle.

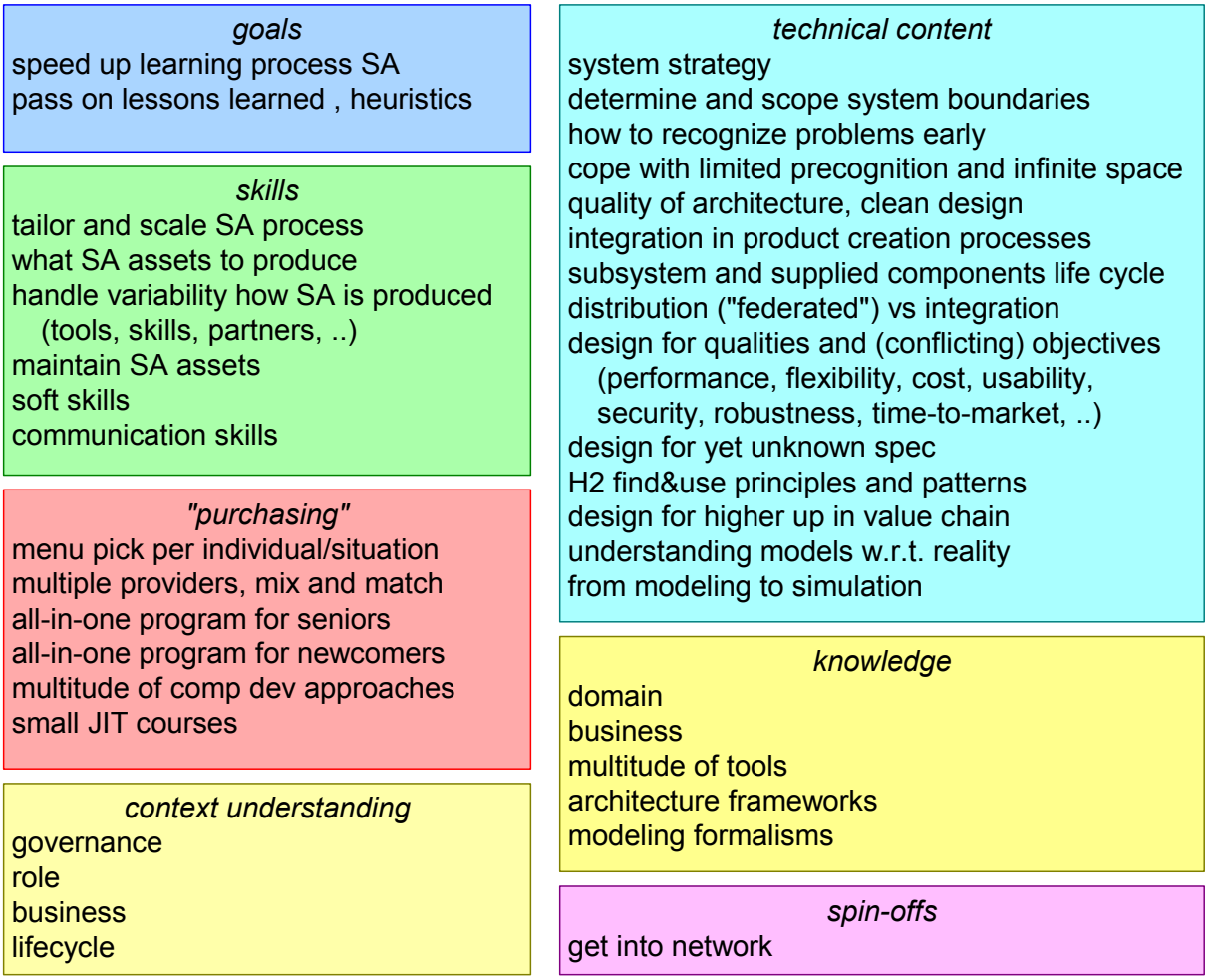

Figure 2 is the outcome of brainstorming about needs for a personal competence development program.

The purchasing requirements for competence development show quite some variation, dependent on the company background. Some companies look for flexibility in subjects (menu philosophy) and flexibility in supply (mix and match of suppliers). Others look more for a complete solution, e.g. one program to help newcomers, or one program for seniors. In the IT (Information Technology) domain the preference was to have courses fitting in limited time (few days), because of work load. The Just in Time Training (JITT) principle, e.g. people

experience the need for the subject and they will have the opportunity to apply what has been learned, is generally applicable, but is more emphasized in the IT domain.

Architects need to acquire knowledge to function well in their role. We identified that the system architect requires both business and domain knowledge to be effective. As expected, that is not sufficient, and the architecting discipline itself has knowledge that should be part of the architect's luggage: tools, architecture frameworks, and formalisms.

The box technical content in Figure 2 shows the technical skills and knowledge that is required. Note that a significant part of the architecting work is technical. Some of this knowledge is domain specific, but many skills are much more generic.

As spin-off of the development program it is expected that architects also have grown their network of competent architects with which to collaborate. A varied and rich network is seen as an important asset for system architects.

4. Three provider programs at a glance

Universities and knowledge institutes offer education and coaching of practical work, from experienced practitioners, as part of competence development of individuals. We shouldn't confuse obtaining a degree in Systems Engineering or Architecting with being a System Engineer or Architect. The idea behind offerings from providers is that they help individuals to become better Systems Engineers or Architects in a shorter amount of time. To this point, there is consensus that considerable actual experience is required to become a Systems Engineer or Architect.

Principle 7.2 Considerable experience is required to become a System Architect. *While education and coaching may shorten the time needed to become System Architect, there is no substitute for experience.*

Stevens Institute

The School of Systems and Enterprises is a school within Stevens Institute of Technology. Stevens Institute is an accredited university in the US, but teaches internationally. The school offers Systems Engineering education at several levels:

- graduate certificate (12 credits) in Systems Engineering
- master's (master of engineering, 30 credits, about two years) in Systems Engineering
- PhD in Systems Engineering

Many different specializations can be chosen, see Figure 3. All master's degrees share the same core set of courses: Systems Engineering fundamentals, System Architecting and Design, Project Management of complex systems, Systems Integration, and a special research project or thesis.

The courses are offered through different modes of delivery. The students can take the courses in a traditional semester format over 14 weeks on campus. Most courses are also offered on-line over the course of a semester. The most popular delivery format for corporate and institutional programs however is the module format. Typical format of a module course is the equivalent of 1 week of pre-reading work, 1 week intense course (lecture and exercises), followed by 10 week homework project. By sending the professor to a corporate location, this format facilitates participants that are geographically distributed for only the 1 week intense course. In some cases, some students have to travel to the corporate location. In other cases the students are already located there, which significantly reduces the travel required for those students.

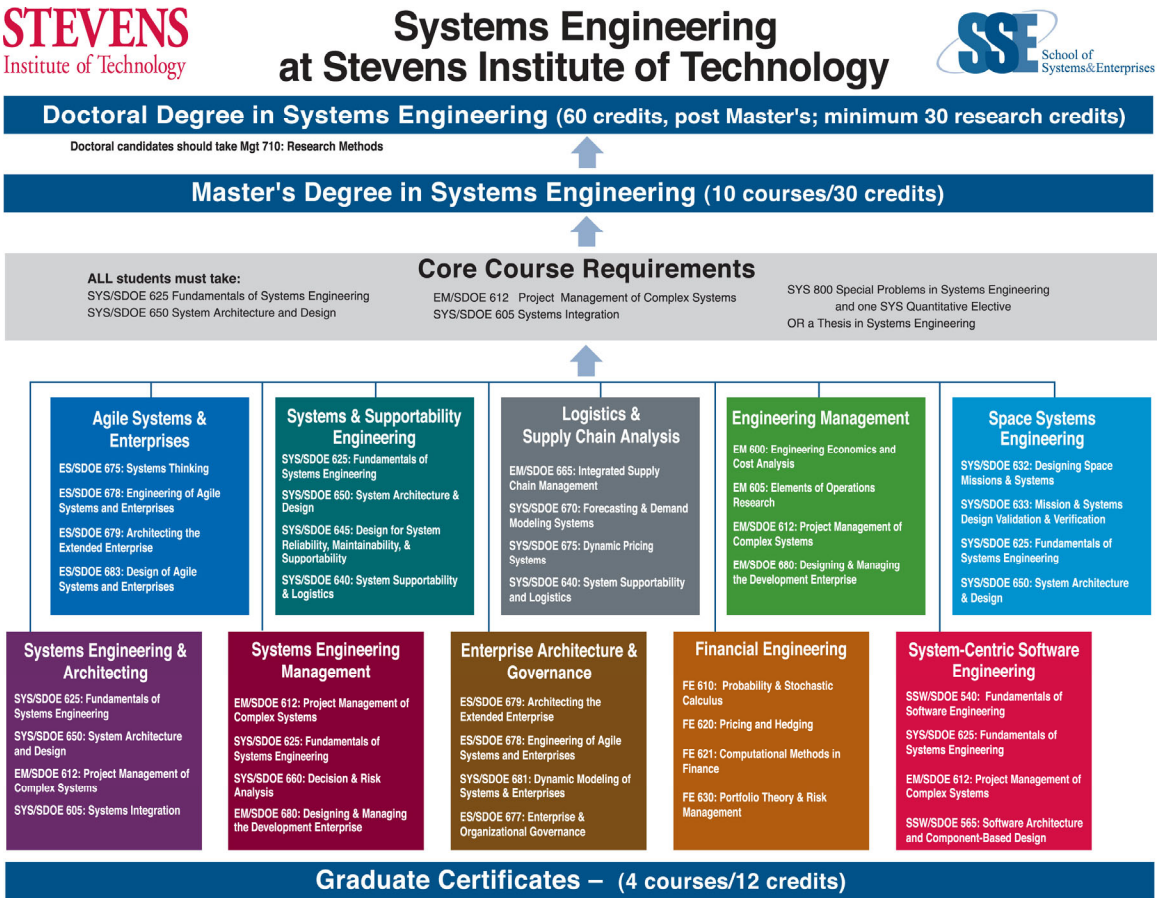

Figure 3, Stevens course program, see also www.stevens.edu/sse.

The Stevens program had been running now for nearly 10 years. In these 10 years the course portfolio has increased from 1 to many specializations. The faculty size and the amount of participants has also increased manifold. Today Stevens Institute operates globally with partners in India, Singapore, the Netherlands, Norway, Sweden, with others under development.

ratio courses : practice	1 : 10
duration	nominal 2 years, student determines actual duration
prescribed or menu	prescribed core; large degree of freedom
accreditation	formal master's
selection	no strong selection; bachelor prerequisite

Embedded Systems Institute.

The Embedded Systems Institute (ESI) in Eindhoven, The Netherlands, is positioned as research institute between industry and academics. It was founded by three industrial companies (Philips, ASML, Oce), three technical Universities in The Netherlands (Twente, Delft and Eindhoven) and one Dutch Research Organization (TNO).

ESI envisions a competence development program in three stages: designer, domain architect, and system architect. For nearly ten years an educational program has been running for the first phase, called *Embedded Systems Architecting*, now renamed into *program designer*. This first phase originally consisted of 25 course days in one year. This program has been extended to 35 course days in 14 months. Personalization is foreseen by offering the courses as modules. Last year ESI developed the second stage of this program as an intense sixteen month curriculum with a mix of 12 lectures, project work and coaching, see Figure 4. In this paper we focused on the second stage *domain architect*.

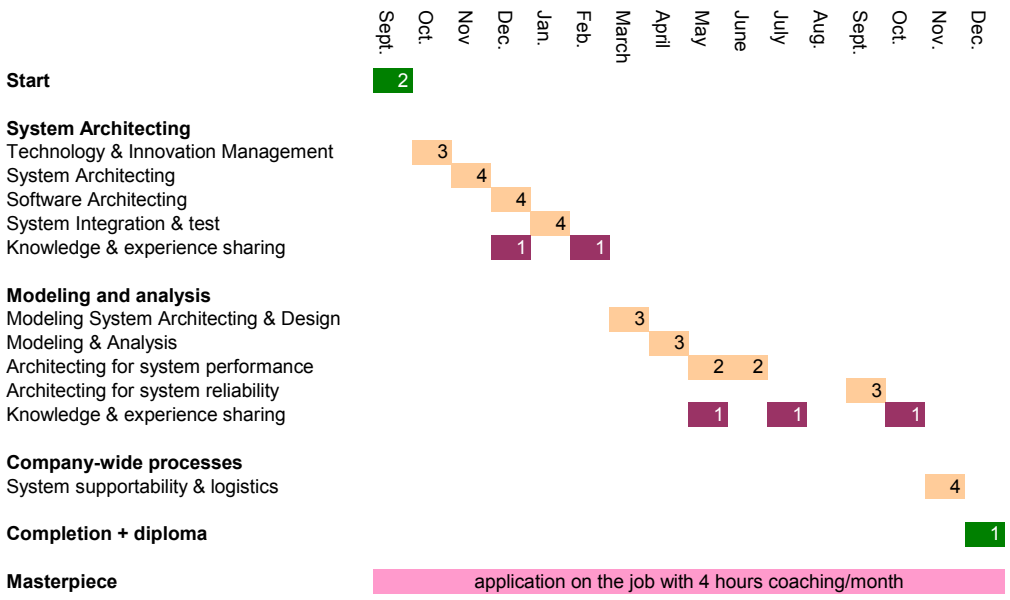

Figure 4, ESI 16 month curriculum for domain architects.

ratio courses : practice	1 : 5
duration	16 months
prescribed or menu	prescribed
accreditation	informal certificate
selection	strong selection via intake

Buskerud University College

Buskerud University College started a Master's of Systems Engineering as part of the Norwegian Center of Expertise for Systems Engineering in Kongsberg. To bootstrap the Master's program, the core curriculum from Stevens Institute's School of Systems and Enterprises is provided in Kongsberg. Meanwhile an accreditation effort has begun to

customize and complement the Stevens offerings towards local Norwegian needs. As a consequence the program is quite similar to the Stevens master's program. However, Buskerud University College provides 4 specializations: Systems Engineering, Control engineering, Embedded Systems, Product design and material science.

The program is followed by three types of participants:

- Industry master students; recently graduated bachelors who are hired by local industry. They need three years of concurrent work and study to get their master.
- Part-time students; experienced engineers doing the master study part-time. They will typically need four years to finish.
- Ad hoc course participants. These participants don't study for credits and don't do the 10 week projects after the course.

The industry master students must have a relevant bachelor degree with good grades. The companies screen the industry master students and select student(s) that fit their company, since the industry master students have to be employed at one of the companies. Part-time students must have sufficient experience and they will have to convince their management to invest time and money in the master study.

The program is now in its third year. The first cohort of industry master students are preparing for their half year research project.

ratio courses : practice	1 : 10
duration	nominal 3 years, student determines actual duration
prescribed or menu	prescribed core; large degree of freedom
accreditation	formal master's (in progress)
selection	strong selection industry master, medium selection part-time, weak selection ad hoc participants

5. Three Company programs at a glance

Raytheon

Raytheon has an extensive company wide program to mature the architecting competence, the Raytheon Mission Architecture Program (RayMAP). The Raytheon Certified Architect Program (RCAP) within RayMAP is an initiative to instruct, assess, certify, and deploy senior systems and enterprise architects across the company. The program addresses architects at different levels of maturity, but its primary focus is for the senior practitioner. The discussion during the forum has focused on the most mature level of developing system architects.

Core to the Raytheon program is a small group of corporate people leading the program. This group has identified the company's required profile for architects and the needs and translated that in a competence development program. Providers were identified from the start that aligned with the program's focus and supported its needs. The Engineering Vice Presidents of the different business units are asked to select candidates for the program. The capacity of the program is limited, so selection is strict and limited to very senior engineers.

Participants can be certified by a certification review board comprised of members from Raytheon's corporate Architecture Review Board. The certification board assesses the fulfillment of a candidate against several dozen documented criteria spanning training, leadership, external certifications, and practitioner experience. Their Raytheon certification needs to be renewed regularly (three years).

ratio courses : practice	1 : 10
duration	nominal 1 year (also several years of practitioner experience), participant determines actual duration
prescribed or menu	prescribed core;
accreditation	formal certification through board
selection	formal selection by Vice Presidents

Philips Research

The program at Philips Research is a grass roots program. It was set up by architects with the support of the Research Management team. The program is targeting junior architects, people with only a few years of experience. The program's duration is six years with a mix of education and on the job training. The participants get a combination of courses, especially in the first year(s). For the on the job training, mentoring is organized and the projects where participants are working on are carefully selected; typical duration of projects is 1 to 2 years to facilitate sufficient exposure to different subjects.

This program has been stopped after about ten years of operation, due to significant changes in the company portfolio.

ratio courses : practice	1 : 5 first year; later mostly practice
duration	6 years
prescribed or menu	prescribed core
accreditation	informal certificate
selection	medium selection by manager and program

Nokia

Nokia is currently working on the setup of a competence development framework. The trigger to begin designing this framework has been the observation that architects become architects by accident and without any guidance on what they should know or experience. Nokia is also concerned with lack of junior architects and wants to "lower the ladder" down so interested developers know how to step up to being an architect.

The first step was to make a matrix of skills and knowledge versus the maturity level of the architect. Skills and knowledge were captured from practicing architects in Nokia and from external inputs (Stevens Institute).

The Nokia development organization is large and operates in a dynamic market where a rich variety of products has to be created concurrently. Technology and market are evolving fast. Architecting as competence must be ingrained throughout the organization in many individuals. The vision behind the concept competence development program is that a rich program is provided, where individuals can pick the appropriate modules for their personal and organizational situation. The maturity matrix functions as reference for managers and architects to determine what possible educational steps could be as part of the architect's personal development.

ratio courses : practice	no fixed ratio
duration	no fixed duration
prescribed or menu	menu based
accreditation	Not applicable (yet)
Selection	Employees chose

6. Discussion and concerns

The programs as described here show a number of similarities:

- Competence development has to be offered at multiple levels of experience
- The duration of the competence program is substantial (many years)
- Core parts of competence development are:
    - Skills; (inter)personal, technical, and situational skills
    - Mentoring/coaching
    - Real work in practice
- The desire to apply the program broadly

Mentioned earlier in this paper are the differentiating factors: *ratio courses and practice*, *duration*, *prescribed curriculum or menu-based*, *formal accreditation or informal certificate*, *strong selection or low threshold*.

Ratio courses and practice, duration, prescribed curriculum or menu-based curriculum, and strong selection or low threshold seem to relate somewhat with the philosophy behind the program. We can make a caricature of two extremes:

- "controlled" development
- "natural" selection of emergence

In the "controlled" development extreme the selection up front is strong. All participants go synchronously through the same program. The duration of the program is more or less fixed. This approach fits well with the managerial needs to be predictable in results and costs. The second phase of the ESI program is closest to this "controlled" development extreme. ESI would like to move to a more modular format, but the size of the program is still too limited to make a modular format sustainable.

In the "natural" selection or emergence extreme there is a large group of employees flowing through the programs, all with their individual selection of subjects and their own timing. Some individuals of the large group actually grow into full system architects. Duration and achieved skill levels will vary a lot. This approach facilitates individual needs. The Nokia program is closest to the "natural" selection or emergence extreme.

The difference in **formal accreditation or informal certificate** is partially caused by different roles and partially caused by differences in incentive. Universities depend on accreditation for their business model. However, the master degree as an accredited degree is only a statement that participants have fulfilled the examination criteria. In other words, the tested knowledge and skills have been verified. It does not provide any indication if the participants are (or will be) good system architects.

The accreditation process at Raytheon goes beyond the knowledge and skill level, by assessing past contributions. This accreditation is at least an indication of past performance. By the requirements to renew accreditation after three years, Raytheon acknowledges that one's

performance is time and situation dependent in that with the rapidly advancing technological advances, one's architecture knowledge may grow stale. Accreditation from Raytheon's perspective is only a snapshot in time.

The Dutch programs (Philips and ESI) are less concerned with formal accreditation. Participants and companies seem to be less interested in accreditation as incentive in the Dutch culture.

Based on the discussions, the participants at the forum created an explicit inventory of **concerns** after discussing all programs. The most dominant concerns were:

- *[Top]* management involvement
- Funding, business model, budget process
- Short term pressure
- The gap between (course) theory and practice
- System architects spend too much time defending their existence to "the others"
- Architects leave after training
- No repeatable, objective way to assess architecture or an architect
- How to get the right people in the program?

***[Top]* management involvement, funding/business model/budget process, and short term pressure** are related concerns. Competence development of system architects is a long term objective based on the vision that architecting is necessary as a prerequisite to develop tomorrow's systems. In financial terms it is an investment in people and their skills, where the return on investment might be years in the future. If top management does not share this vision it is difficult to create funding for the program and to counter balance the ever present short term pressures.

The gap between (course) theory and practice translates into requirements for the selection of courses. It should be noted that some theoretical stretching of practitioners is desirable. Part of the value of courses is to get participants out of their established practices

and refresh their reference framework. Nevertheless, some academic oriented courses are not practically deployable and frustrate participants rather than inspire them; those courses should be avoided.

Competence development of the organization, as discussed in earlier section, addresses the common problem in which **system architects spend too much time in "defending" the need for a system architect, or the need for explicit systems architecture to others**. Unfortunately, this counter measure depends again on the shared vision of top management on architecting; if that vision is not shared, then architects have to fight an uphill battle.

The fact that **architects** may **leave after training** is a serious concern; and it has been observed many times in practice. This competence development of individuals creates more awareness of organizational and business status. When the architecting processes do not function well and educated architects feel that improvement is out of their scope of influence, then changing organization is an option that is considered. Again this phenomenon emphasizes the importance to develop the organizational competence concurrently with individual competence.

No repeatable, objective way to assess architecture or an architect limits feedback loops. How should an organization provide feedback, if assessment of architecture and architect depends strongly on the assessor? It was decided this will be the topic for the next forum meeting - ***assessing system architecture***.

How to get the right people in the program? This concern relates to the concern of assessing (potential) architects. Nevertheless, we concluded in the discussion that going through (part of) the competence program also brings value to people who don't become a systems architect after all. One important realization is that organizations, nor individuals, should view the inability to complete such program as failure. Quite the opposite is true, and from it we formulate the following principle:

Principle 7.3 *Architect competence programs also bring value to participants that do not finish the program or do not become a systems architect in the end. The broadened perspective and the training of skills are of value in many roles in the organization. The gained insight in architecting helps to share the role of architecting throughout the organization.*

7. Lessons learned

Embedding systems architecture in the organization is a key success factor. As discussed in section 2, the organizational competence has a significant impact on the effectiveness of individual systems architects. The presence of an Executive champion within the organization is directly related.

Training is needed at multiple professional maturity levels. Competence development requires a substantial duration. At each level, and for the full duration the program different skills must be addressed: personal, technical, and situational. Competence development is much more than training; building up experience is crucial, for example through on the job training, through job rotation, and by mentoring. Participants should be exposed to a broad spectrum of experiences to see many different disciplines and technologies, to build up a rich collection of architecture patterns and to see many different system qualities.

8. Summary and Conclusions

We have compared 6 different programs from different companies and providers. We also discussed the needs for these programs and the concerns arising from each program in this white paper. We started the discussion with 4 questions. We will revisit the 4 questions and attempt to summarize the answers as far as they were addressed in the discussion.

How should organizations and individuals develop System Architecting Competence? Both organizational competence and individual competences need to be developed. Since we have focused mostly on the individuals, there is still no concrete answer for the question on

developing organizational System Architecting Competence. The subject of organizational competence development deserves an entire forum meeting, although it was remarked that this meeting only makes sense if we have sufficient collective experience.

How should System Architects be Educated? The consensus in all cases is that a combination of experience and training is necessary. The competence development programs strive in many ways to maximize the learning on the job in combination with carefully timed training. The training addresses other skills; soft skills being a significant part of the training.

How should an organization identify and select potential System Architects? Many programs select candidates up front. The selection is done by their managers, by peers, or by HRM (Human Resource Management) specialists. Nevertheless, the selection process and criteria does not seem to be well understood or well defined. This subject may deserve an entire forum meeting.

How to educate, train, and instruct management in dealing with System Architects? We discussed this question mostly in the margin. It seems this question is part of the much broader question how to develop organizational competences. This question might also deserve an entire forum meeting. The collection of forum members might have sufficient experience in this subject, so this might be a step towards the broader organizational competence development.