The Systems Engineer: a Communicating Saté Skewer

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Abstract. Communication is recognised as an important ingredient to execute projects. It is not just a single capacity, but can be drawn along multiple dimensions. This paper describes the Systems Engineer as a 'Communicating Saté Skewer', addressing his ability to concatenate different aspects (people, means and content) to secure that the system becomes successful.
To be able to act as a good Systems Engineer, this paper describes six dimensions that are important for optimal communication and to fulfil the role of 'concatenater' of content. These dimensions range from the organisational- and system hierarchy to the intercultural aspects of communication within and between teams or organisations. Moreover these dimensions vary from East to West. Trying to find a person who meets the needs along all dimensions may result in looking for the impossible. Some thoughts are given that may help constructing a balanced team that meets the project needs.

Introduction

During the opening session of the INCOSE International Symposium 2004 in Toulouse, the master of ceremony, Paul Davies, asked the audience the following question: "How can one tell the difference between an introvert and an extrovert engineer?". The answer to this question was that the extrovert engineer looks at you while talking, but he is looking at your shoes. After unveiling this answer, the audience widely started to laugh. However, this joke illustrated a serious communicational problem that traditionally can be encountered with members of certain disciplines. Engineers are generally considered to be one of those less communicative disciplines. One of the key competences of a systems engineer is the ability to communicate. On the one hand this requires good communication skills with many people at various levels of the project, the organization and last but not least towards all stakeholders. On the other hand it requires sound underlying content and messages. Hence skills, experience and knowledge are important.

The ability to communicate becomes especially important in ever increasing complex projects with shorter technology lead times and greater impact on the environment. An environment in motion means also uncertainty. Hence managing complex projects and systems engineering, means managing uncertainty.[1] The Systems Engineer faces a new challenge of being superman. Skills, knowlegde and experience become extremely important in changing environments.
Grasping the complexity of projects, under these circumstances, is understanding the composition, its purpose and its context. It is about the 'meat' of the project. Something you

[1] Dombkins D.H., 2007 "The integration of Project Management and Systems Thinking", IPMA Project Perspectives

can eat, digest, swallow. Although the meat might consist of pieces, the meat is part of a meal. It should be concatenated as a comprehensible set of building blocks. Here the analogy with a saté skewer pops up. The Systems Engineer is able to act as a communicating saté skewer. Concatenating the meat of the project as a coherent part of the meal. As you might know saté skewers have many international appearances from East to West: yakitori, shish kebab, brochette, shaslik...... The same holds for the Systems Engineer. His ability to communicate and to grasp complexity is subjected to cultural differences and behavioural styles.
This paper draws a profile of the Systems Engineer as communicating saté skewer, along its various dimensions.

Some examples

Risk Management. Risk management and systems engineering are closely related. According to ISO-15288 and CENELEC-50126 risk management is the leading principle within systems engineering. However, too many projects treat risk management as a separate discipline. Risk management has become an exercise of the "project management team". Risk analysts organize periodically special risk brainstorm meetings with various participants. Afterwards participants are happy to return to the real work. As a result the risk register is often vague and contains too many risks, concerns or even worse: incidents. Establishing risk management as a powerful project steering tool poses new challenges on the Systems Engineer.
During the implementation of Systems Engineering at the Dutch Railway Infrastructure business, several pilot projects were carried out to answer this new challenge for the Systems Engineer. Some elements of the approach are very similar to the BMW approach as described by H. Negele et al[2]. In distinguishing the enterprise levels the project starts at the transition from the environmental level to the system level. Typical engineering risk management activities at this transition are described as follows:

Table 1: Engineering Risk Management Activities

Level	*Roles/Party*	*Activity*
0	Clients Systems Engineers	Stakeholder and context analysis revealing the business interests and relevant (external) interfaces as a basis for the specifications.
1	Project Control Systems Engineer	Based on the stakeholder an context analysis, problem areas can be identified. These problem areas are matched along two axes in a matrix: the project management aspects (time, money..) and the System Breakdown. The matrix contains the names/roles of persons to be interviewed on the intersections.
1	Contract Management Systems Engineers	The interviews support the translation from problem areas to risks. Decomposition of risks. The next step in the process is to identify risks which can be allocated to a single party. This needs both a contractual view and system breakdown view.
2	Specialists Users of the system Systems Engineers	Sometimes it is hard to determine the impact of the risk on the business interests and specifications. These risks are subjected to further investigation with parties involved at the detailed level.
0	Project Management, Systems Engineers	At this stage one is able to draw up a risk register, which is fully transparent and can be accounted for. The project manager takes care of formalising the commitment of all parties involved for the risk register and allocation.

Level 0 = parties outside of the contract (customer, stakeholders), Level 1 = parties at system level, Level 2 = parties at subsystem level and/or contractors

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[2] Negele, H., Wenzel, S., Pfletschinger, T.and Getto, G. 2005. Successful Implementation and Application of Continuous Risk Management to Complex Systems Development in the Automotive Industry; *INCOSE*

The above example describes different types of Systems Engineers who are able to act among various parties involved and on different system levels. He concatenates the business, the systems and its risks and is able to communicate: the communicating saté skewer! As a result, risk management provided much more focus on the real hot issues to manage. Moreover the allocation of risks among participants became transparent and accountable.

Verification & Validation. This is one of the activities that takes place throughout almost the entire lifecycle of a system and/or project. As we start defining the need of the stakeholders, followed by the definition of the required system, we also begin thinking about the way the requirements are verified and validated. This process continues during the system development, system realisation and not to forget the system operation period.
As an example we do a quick scan of how things were organised for the superstructure of a high-speed rail line[3] , developed and constructed in the Netherlands between 2001 and 2007. Based on the already realised sub-structure, a set of ±600 requirements and other contractual documents was agreed. Several organisations and parties were involved in the Verification & Validation process. Some are listed below:

Table 2: Verification & Validation Activities

Level	*Roles/Party*	*Activity*
0	Customer – V&V management	Safeguard that all requirements are being met
0	Fire department	Safeguard that all of their stakes concerning fire safety for passengers, personnel and people in the vicinity of the system. Their involvement depended on the design choices made.
0	Cities & communities	Safeguard the interest of people living, working and travelling near the system and within their community boundaries
1	Systems Engineering team	A team of ~15 Systems Engineers from different generic fields of interest (signalling systems, Catenary system, etc), lead by a team of three Systems Engineering Managers to secure integrity. Each Systems Engineer safeguarded the system and subsystem integrity and compliance towards (a subset of) the system requirements. The Systems Engineer makes a compliance statement , covering the subsystem and system compliance with the requirements.
1	System V&V management	Facilitating the means to manage the compliance with requirements on systems and subsystem levels. Wrapping-up all relevant evidence for showing compliance with the requirements
2	Subsystem Engineers	Each subsystems engineer safeguarded the subsystem and components integrity and compliance towards (a subset of) the apportioned subsystem requirements. This also included off-the-shelve components.
1	Maintenance Company	After the system is accepted by the customer, the system is maintained by a maintenance company that on a regular basis proves compliance with the system requirements.

Level 0 = parties outside of the contract (customer, stakeholders), Level 1 = parties at system level, Level 2 = parties at subsystem level and/or contractors

From the system perspective, communication continuously takes place with:
- the customer and stakeholders to secure mutual understanding of the meaning of the

[3] Elich E, et al. 2008. "Paradox of the Bermuda Triangle; Applying Systems Engineering in a PPP-environment", Utrecht, *INCOSE*

requirements and the correct implementation of the requirements. This also involves understanding the background and business rules behind the requirements
- Systems Engineers to control the integrity of the subsystems and the system as a whole
- subsystems engineers to secure and understand the way the requirements are being met with in the design and realised subsystem

The system contractor consisted of organisations that originated from the Netherlands, Germany , UK and USA. Cultural differences between team members from these countries gave a special dimension to the communication between them. In short; a Anglo-Saxon based contract was managed by a mainly Rhineland oriented project team.

Communicating Saté Skewer

As described before the Systems Engineer concatenates different aspects (e.g. risks, context, money and business). He must be able to communicate with all types of stakeholders. We would like to introduce the concept of the "Communicating Saté Skewer". First the dimensions of the task area of a Systems Engineer are explained.

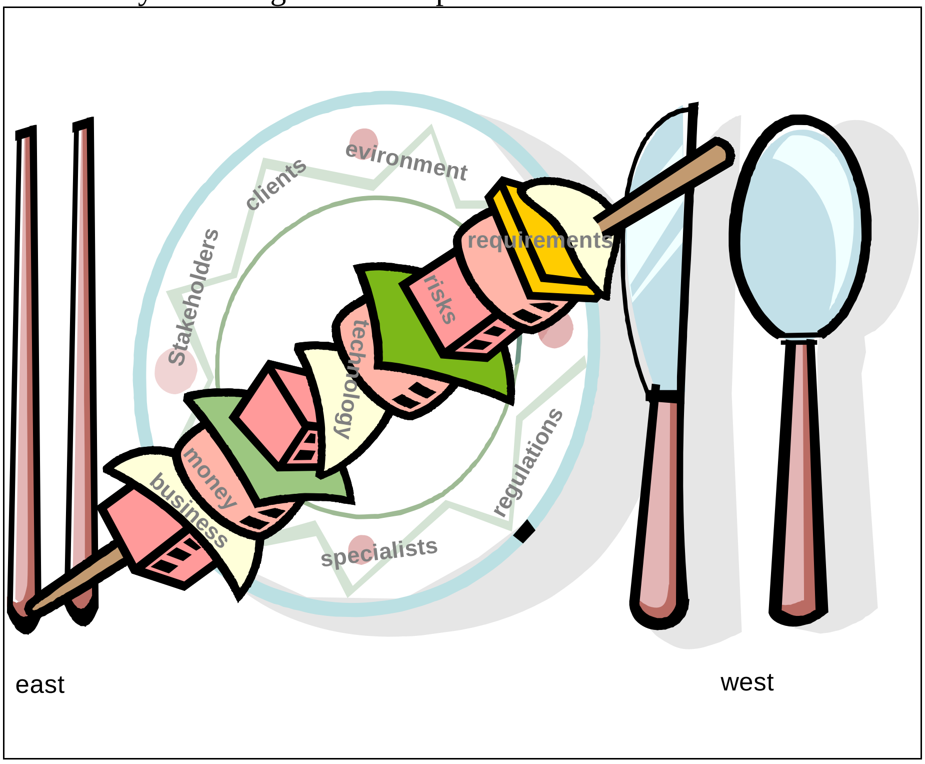

Figure 1 The communicating saté skewer

The dimensions

As illustrated before the Systems Engineer has to act along various dimensions. In practice the authors have recognized that the dimensions should combine skills and content. Most profiles however treat these dimensions separately. Integration of the following six dimensions provides good guidelines in establishing balanced teams of Systems Engineers:
- System Hierarchy
- Organization Hierarchy
- Behaviour Style
- Long/short term orientation
- Generic view versus Specialist view
- Team player versus Soloist

System Hierarchy. In systems engineering a system is decomposed in different levels of hierarchy. The INCOSE Systems Engineering handbook, version 3, and ISO 15288 recognise the following three levels: System of Systems, System and System Element. In certain domains other decomposition levels are being used. Parties in the civil construction industry in the Netherlands have agreed[4] on using the terms 'System', 'Subsystem', 'Component' and 'Element'. In any of these cases the range in abstraction can become very large, potentially resulting in difficulty for a person to cover knowledge and feeling for the whole range. Some people are very good in tackling high-level abstract approaches of a system, while others feel comfortable dealing with specific problems with limited boundaries. In quite some cases the principal is strong in defining the system of systems, where the contractor is strong in solving the element level problems. So, who is covering the system level integrity and the link towards the system of systems as well as the elements? Yes indeed, the communicating saté skewer does.

Organization Hierarchy. Henry Mintzberg described an organizational configurations framework with six setups.

Depending on the dominating setup the organizational configuration has a different appearance (professional, innovative,…..). In fact the dominating setup determines the real hierarchy in the organization. The ability of the Systems Engineer to influence this dominating setup is key to the success of his proposed design solutions. His position and the distance to the real power is leading. Hence hierarchy and (obsessive) leadership might detriment the role of the Systems Engineer. This is the very reason why Henry Mintzberg stressed the concept of community-ship in stead of leadership in one of his articles in the Financial Times.[5]

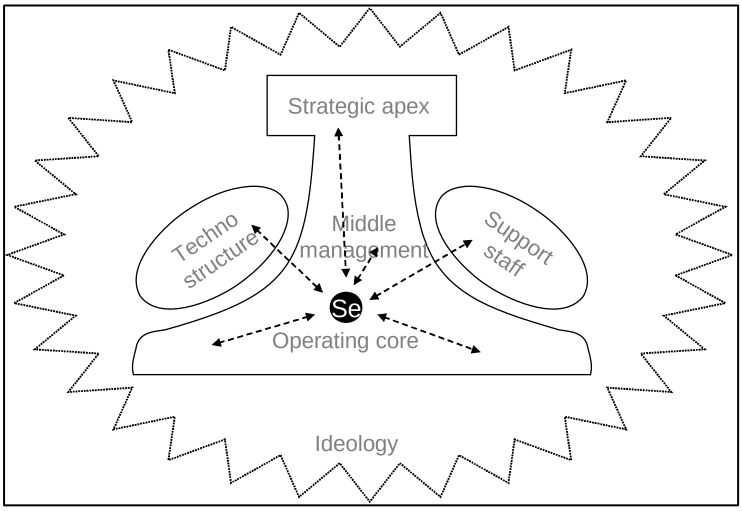

Figure 2 Mintzberg organization structure

The distance to the real power is a measure for the effectiveness of the Systems Engineer

Behaviour style. According to the Life Style Inventory model[6] behaviour can be roughly classified as defensive, constructive or aggressive.

- Defensive styles can produce a predictable and secure situation, but at the cost of learning, adaptability and ultimately survival. Typical behaviour is to avoid and withdraw from threatening situations.
- Constructive styles account for synergy and keep the balance between people and results.
- Aggressive styles: Though sometimes temporarily effective, aggressive styles may lead to stress, decisions based on status rather than expertise and conflict rather than collaboration.

[4] Leidraad Systems Engineering in de GWW sector (Guideline Systems Engineering for public Works and water management), April 2007

[5] Mintzberg H. 2006. Community-ship is the answer. *Financial Times*

[6] Jones Q. 2005. Organisational Culture: Establishing what makes an Organisation Attractive. *"Recruitment, Training & Retention for the Engineering Sector: Addressing the Skills Shortage" Conference 2005*

Although at first sight one might say that the “constructive” style is the preferred style, both defensive and aggressive styles have their benefits, if applied in balance. Aggressive styles may help the Systems Engineer to step up front and push new ideas, to get things done in complex environments. The defensive styles are required to consolidate and control the project. For example configuration management requires some defensive behaviour. Constructive styles are required for requirement analysis and stakeholder commitment.

Long Term Orientation. this is the ability to take long term aspects of a system into account. Of course, this balances the short term orientation of people. Long term orientation (LTO) for instance involves the capability to cover the entire lifecycle of a System or even a System of Systems. Where for people with a short term orientation, the focus often is on a single step or stage in the process. As an example; if an project team’s responsibility is to engineer and construct a system and they are not accounted for the system maintenance, one sometimes sees that the short term results dominate the long term interest of the system and it’s stakeholders. In the Communicative dilemma section of this paper, further information about the long term orientation is provided. It discusses the culture related differences concerning LTO, based on research by G. Hofstede.

Generic view vs. Specialist view. The gossip about managers is that they are so generic that the know nothing about everything. From the Systems Engineer however we expect a t-shape[7] profile (see figure3). He has detailed knowledge on various subjects and is able to relate the detailed knowledge within a holistic view.
Some knowledge can not be decomposed, either you know how to deal with “finite elements analysis” or you don’t. The ideal Systems Engineer has a broad horizontal cross-beam and preferably more than one vertical scaffold poles.

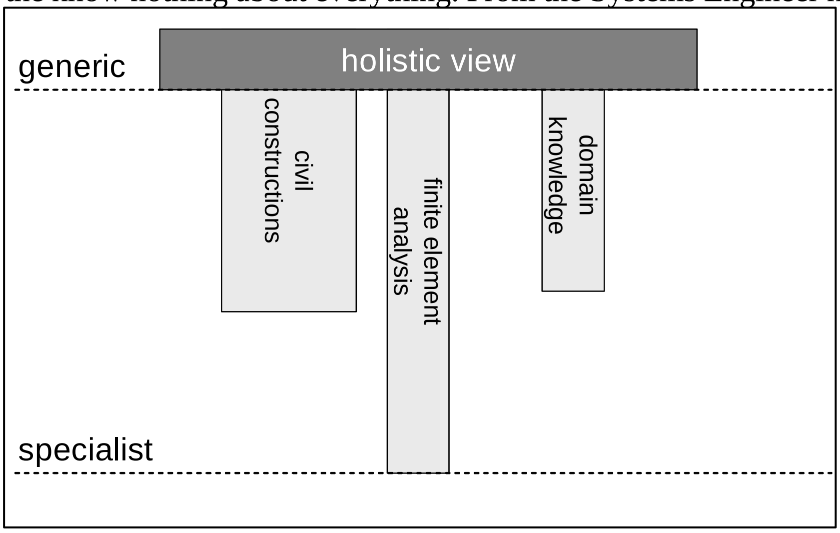

Figure 3 T-profile

Team player vs. Soloist. In line with the riddle about the introvert / extrovert engineer, a distinction can be made between team players and soloists.

The ultimate team player is a communicative person who likes to interact with other people and can be qualified as being extrovert. A team player typically acts in teams along both the Generic/Specialist and Close power/Distant power axes. As indicated by Heinz Stoewer in multiple presentations, a Systems Engineer is somebody that “communicates, communicates and communicates”. By clear communication topics can be addressed and coped with accordingly.

The soloist can be given a specific problem to solve or a systems engineering tool to manage. For this activity the need of communication with other team members or external parties is limited. In some (immature) domains, the Systems Engineer is associated with the specialist that manages the requirements and verification & validation tool. However, in that case he or

[7] Weggeman, M. 1997. Kennismanagement: inrichting en besturing van kennisintensieve organisaties; *Schiedam, Scriptum.*

she acts more like a data manager than as a Systems Engineer. In the Dutch civil construction industry systems engineering was widely introduced in early 2007. For many organizations in this industry the systems engineer is equivalent to a data manager.

Based on the dimensions described above we can draw a profile of the Systems Engineer. In the introduction we quoted the archetype of an introvert Systems Engineer. His profile might look as the profile of figure 4. The dotted line indicates the profile of a more extrovert systems engineer.

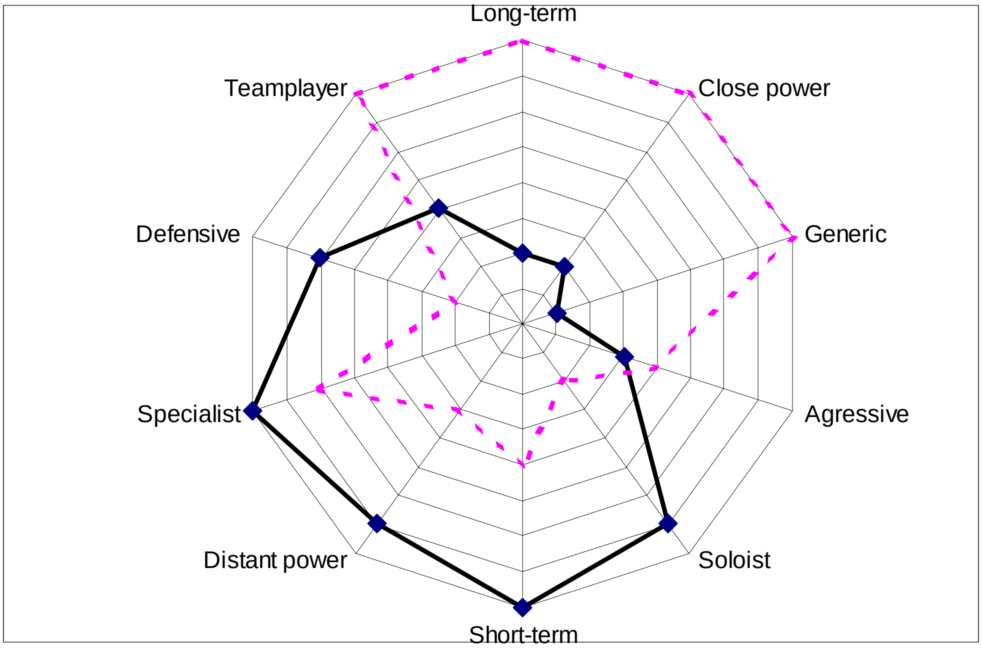

Figure 4 Example profiles of a Systems Engineer

The dilemma

While looking for System Engineer(s) for your project, several dilemmas occur. Here two dilemmas are explained: 1) finding one person that meets all expectations of a Systems Engineer tends to be looking for the impossible. 2) Different cultural backgrounds may lead to an unexpected source of conflict.

Dilemma 1: If we have a project that needs systems engineering capabilities that score high on all axes, we might be looking for the impossible if this should be covered by one person. Especially for small projects where the role of the Systems Engineer is to be performed by one person or even combined with the role of project manager. For both small and large projects the actual need must be identified and distributed over the people that make the team. This approach has proved to be a success for the Sciamachy project team of Space Research Organization Netherlands. For this project a coordinating team of five associates covered project management-, and systems engineering activities from system-, electronic-, software-, physics- and mechanical perspective. They were responsible for the integrity of the entire system and all of them could be characterized as strong Generic and Team player oriented people. This balanced team effort was the key for success.

Dilemma 2: While a balanced team is put together, another danger might threaten the successful execution of the project. In this time of globalization, more and more projects are being executed by a team of people with a multi cultural background. This requires awareness and knowledge of intercultural communication. Geert Hofstede has done years of research on the cultural differences in the values and standards of people from different countries and regions. To quantify these differences, Hofstede has identified the following five aspects: Power Distance Index, Individualism, Masculinity, Uncertainty Avoidance Index and Long-Term Orientation. Detailed information ca be found at www.geert-hofstede.com[8] .

The four graphs below show an interesting difference between the average people from the three regions (Asia, USA and the Netherlands) and the world average. Especially the wide gap between Asia and the United States related to the degree of Individualism and Long-term Orientation is striking. As an example of the average European country, the Netherlands seems to be close to the world average. For Individualism, the Netherlands is more similar to the American average. This graph shows what we should be aware of as we do business with each other and compose teams while East meets West. As long as we understand the difference we can deal with it. As soon as we don't notify the difference, unexpected conflicts may happen at any moment.

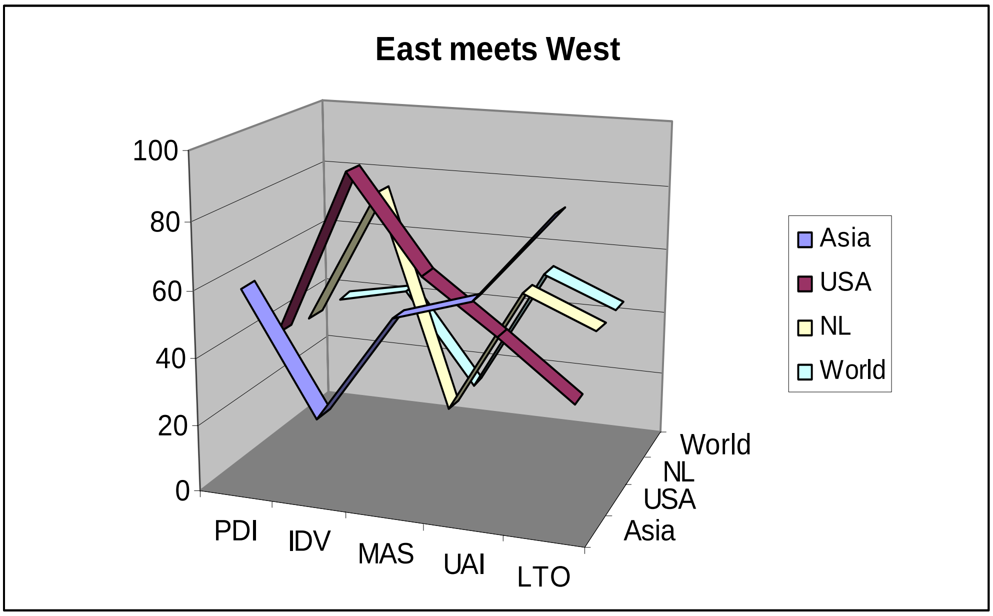

Figure 5 East meets west according to Hofstede:

Like we have seen in the example project for Verification & Validation activities, these Hofstede aspects differed substantially for the people with their German, Dutch and British backgrounds. The application of the Hofstede analysis to Systems Engineers, was also discussed in a paper by E. Herzog et al.[9]

Team composition

In stead of looking at the individual Systems Engineer, the only solution to the dilemmas is a balanced team approach. This team approach should be applied at two levels:

- Within the project team
- Among the project teams involved (principal, supplier)

At initial project start-up the staffing is often recruited based on the required specialists. All specialists together don't establish a team. For small projects only a limited number of candidates are available as discussed before.

[8] Geert Hofstede website, www.geert-hofstede.com ,with elaborated information about cultural specifics per country/region
[9] Herzog E, et al, 2007, Cultural Differences – and how they affect Systems Engineering, *INCOSE*

Using the profile of the six dimensions reveals the capabilities of the team versus the needs of the project. Not every project requires the same profile. An innovative project requires a different profile compared to a project with a lot of standard building blocks. Once the team profile and the project profile are defined one can start tuning the team. Given the size of the team this might be done either by adding functionaries or re-allocating roles. In the latter case the project manager might assist the systems engineer in specifying the client requirements if the systems engineer has a too defensive behaviour style.

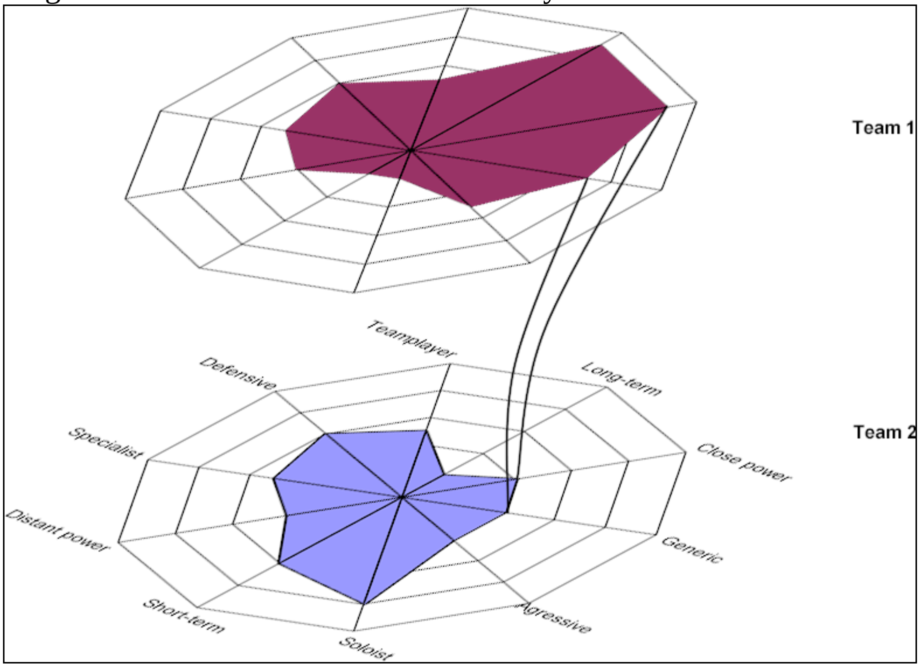

Figure 6 Matching team profiles

It is not sufficient to optimize the profiles within the project team. During project execution often a functionary matrix is established between principal and supplier, defining who is communicating with whom. However in practice it appeared that the profiles of the functionaries and the teams are not aligned. Identifying the profiles of the teams along the six dimensions helps in finding mismatches (see figure 6). A systems engineer, who is very much focused on the abstract long term level, will have problems in communicating with a systems engineer with a short term detailed orientation. This communication gap becomes even worse when both systems engineers originate from different cultures.

Conclusions

1. Communicative skills are essential to achieve good Systems Engineering. Here the skills of the Systems Engineer clearly differ from the average engineer / specialist.
2. Increasing complexity and impact on the environment put new challenges on the role of a systems engineer.
3. His ability to communicate and integrate business and solutions becomes critical
4. The systems engineer should develop personal skills and experiences along six dimensions
5. Adequate coverage of the six dimensions requires a team approach
6. Awareness of multi-cultural differences provide chances for parties concerned, where unawareness is the source of conflict
7. The co-operation between principal and suppliers is sustained by matching the team profiles.

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Biographies

Erik Elich is an independent consultant in change and engineering management. Apart from the public sector he gathered his knowledge and experience in the electronics, defence, medical, banking, and IT industry. Erik holds a Master of Science in Electrical Engineering (1984, Delft University of Technology). He started with the application of Systems Engineering in 1984 when introducing Just In Time production principles within factory automation. In 1991 he founded Monto and holded various project management and consultancy positions, lately within the transportation and civil construction industry.
Erik is fascinated by the "suspense of old and new, between now and endurance ". His device is balance in change.

Paul Schreinemakers holds a Bachelor's degree in Fine Mechanics and is a Master of Science in Engineering Product Design. He teaches the application of Systems Engineering within both projects and organizations. Paul has 18 years experience in developing products in various domains.
In 2003 Paul founded his own consultancy company, called SEPIAdvies. Aside of activities for costumers in the domains of Space and Defence, he also applies Systems Engineering in the transportation and civil construction industries. Many of the projects he was involved in consisted of multi-lingual and multi-cultural project teams.
Paul became involved in INCOSE in 2000, and has served for 3,5 years on the board of directors of the Dutch chapter, of which he now is a former President. He was member of the Dutch Special Interest Group Systems Engineering Implementation, creating a step plan for implementing SE within organisations. In 2006 Paul was the co-chair of the European Systems

Engineering Conference, as held in Edinburgh, Scotland. Last year he was the general chair of the IS2008 host committee.