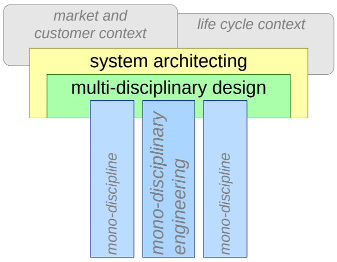
Buskerud University College: Program Systems Engineering

-



Gerrit Muller
University of South-Eastern Norway-NISE
Hasbergsvei 36 P.O. Box 235, NO-3603 Kongsberg Norway
gaudisite@gmail.com

Abstract

The focus of the Systems Engineering program of Buskerud University is on multi-disciplinary design fitting in the market and application needs and usable in industrial engineering processes. The research agenda focuses on reliability in rough circumstances and on innovation or agile architectures. As application domains the research will focus on system and supply industry as present in Kongsberg, such as sub-sea.
This is a rather preliminary agenda, under discussion with the Buskerud stakeholders.

version: 1.4 status: preliminary draft September 6, 2020

1 Introduction

The discipline *Systems Engineering* is instrumental in integrating the work of multiple engineering disciplines to create systems with desired system characteristics. In industrial practice both the system level definition and the detailed designs are well documented. Unfortunately, the multi-disciplinary step in between is much less understood.

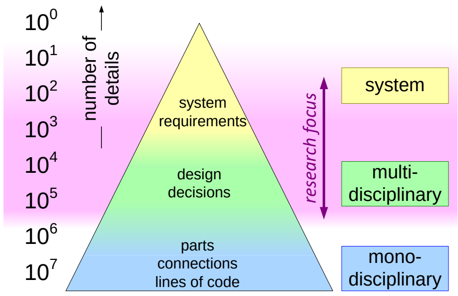


Figure 1: SE: address the gap between System and Realization

Figure 1 shows that systems can be viewed at different levels of abstraction. Contemporary systems need millions of details to describe its design completely. However, we can also view the system at top level by describing ten *key performance parameters*. When we move from system level views to more detail, then we enter the area where multi-disciplinary design decisions are taken. Still more detailed design decisions tend to be mono-disciplinary by nature; we finally make electronic, mechanical or software components.

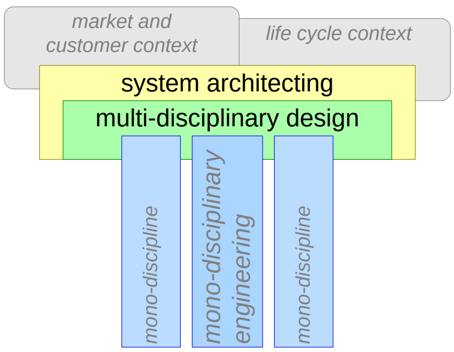


Figure 2: Systems Engineering = Systems Architecting + Multi-Disciplinary design

System engineers need an engineering education in one of the conventional engineering disciplines. Only with sufficient mono-disciplinary engineering understanding they will be capable to integrate the work of multiple engineering disciplines. The in-depth understanding of one mono-discipline helps systems engineers to quickly obtain some insight in neighboring disciplines. System engineers add value by their multi-disciplinary capabilities. They don't need in-depth understanding of all mono-disciplines, because they rely on mono-disciplinary experts for this in-depth understanding outside their own original discipline.

Figure 2 shows that *Systems Engineering* is the combination of *Systems Architecting* and *Multi-Disciplinary design*. The *Systems Architecting* effort connects the context of the system and its creation to the design decisions. System Architecting requires insight in:

- stakeholders
- concerns
- value chain
- business models
- requirements
- system life cycle
- development life cycle
- supply chain
- ConOps (Concept of Operations)

Typical System engineering skills are:

- systems architecting (relate system design to stakeholder needs, identify key drivers, making appropriate trade-offs)
- system design (functional and physical decomposition, interface definition, allocation, modeling and analysis)
- system integration
- risk mitigation
- systems thinking
- support decision making
- support innovation
- reviewing specifications, designs, results

Buskerud University is a small university surrounded by a set of world class high tech industries. We want to provide *Systems Engineering* masters education at international competitive level. To that purpose we will partner with other *Systems Engineering* partners, such as Stevens Institute in Hoboken USA and the Embedded Systems Institute in Eindhoven, the Netherlands.

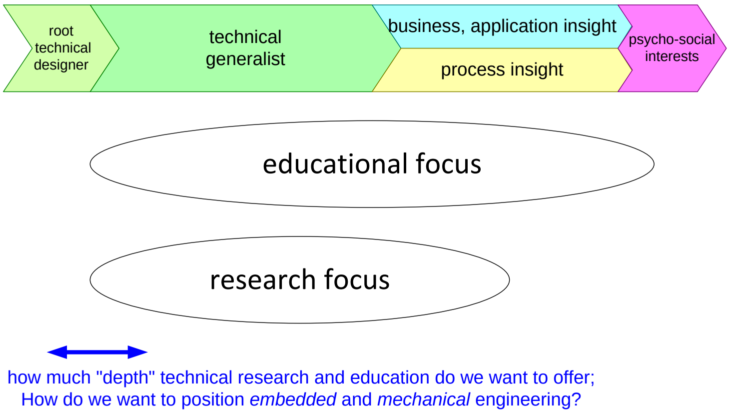


Figure 3: Focus of Buskerud SE program

Figure 3 shows the focus of Buskerud relative to the growth direction of system engineers. This growth is depicted at the top. As indicated above *System Engineers* start with an in-depth conventional engineering discipline. They broaden their technical know how and they also need the means to understand the contexts. Mature *System Engineers* also take into account the many psycho-social aspects that play a role in the market as well as their own companies.

The Buskerud education program has to cover the technical broadening needed for the Multi-Disciplinary design, and it has to cover the understanding of market, application, processes and organizations. The Buskerud research program will slightly more emphasize the multi-disciplinary design to provide an optimal connection with available competencies.

Figure 4 elaborates the educational positioning and indicates the contributions of partners and third parties. The Buskerud technical electives have a clear technological focus, connecting again to the industrial available strength.

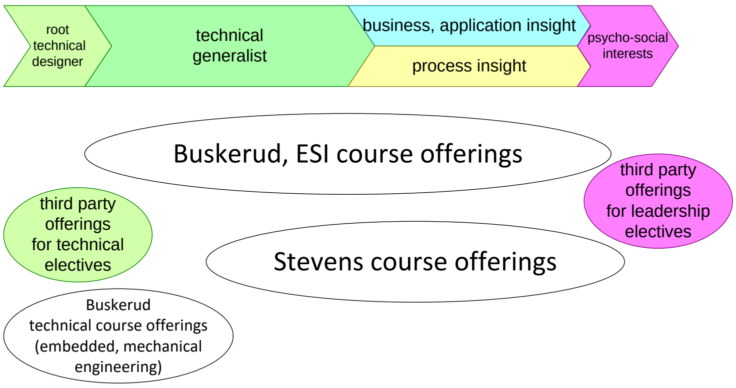


Figure 4: Educational Focus

2 Research Agenda

The *Systems Engineering* research agenda of Buskerud University will focus on the industrial domains of the region, such as defense, deep sea, manufacturing and maritime. We will address *Systems Engineering* in general with a special focus on the following qualities:

- reliability / robustness in harsh environments
- innovation /responsiveness for change

Figure 5 shows the outline of the Buskerud SE research agenda.

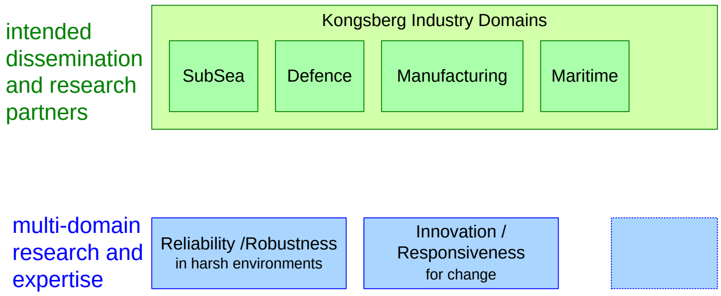


Figure 5: Preliminary Buskerud Research Agenda

Figure 6 shows the research agenda as graph. At the left hand side of the graph shows global trends and consequences of these trends that are relevant for the *Systems Engineering* discipline. The trends are:

number of features increases

performance expectations increase

number of different products increase

release cycle time goes from years down to months

openness increases requiring more interoperability

hype and fashion increase

time to market needs to decrease

development costs increase, decrease is needed

globalization of use increases

globalization in development and logistics increases to benefit from low wages

With the following consequences:

overview decreases, relates to increased size and complexity in decreased time

feature interaction increases between existing and new features, often not foreseen

complexity increases due to most of the trends

amount of software increases; most systems show an exponential increase in the amount of software

integration effort increases, relates to all other consequences mentioned before.

reliability decreases, same causes as increased integration effort.

uncertainty increases, again due to size and complexity. External factors, such as hype and fashion, also increase uncertainty.

dynamics increase; life cycles get shorter, while market expectations increase; lots of concurrent activities with many different rhythms.

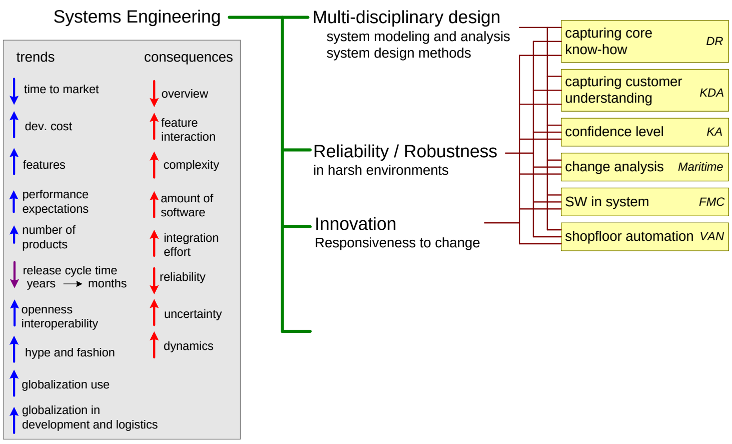


Figure 6: Buskerud research agenda as graph

Systems Engineering is one of the disciplines that addresses these trends and consequences. Our research will focus on improving overview and coping with increased complexity by system design methods and system modeling and analysis. For the chosen domains *reliability/robustness in harsh environments* is a common concern. Some solutions that are proposed for improved reliability and robustness tend to conflict with innovation. For that reason we will address the innovation and the responsiveness for change concurrently in our research.

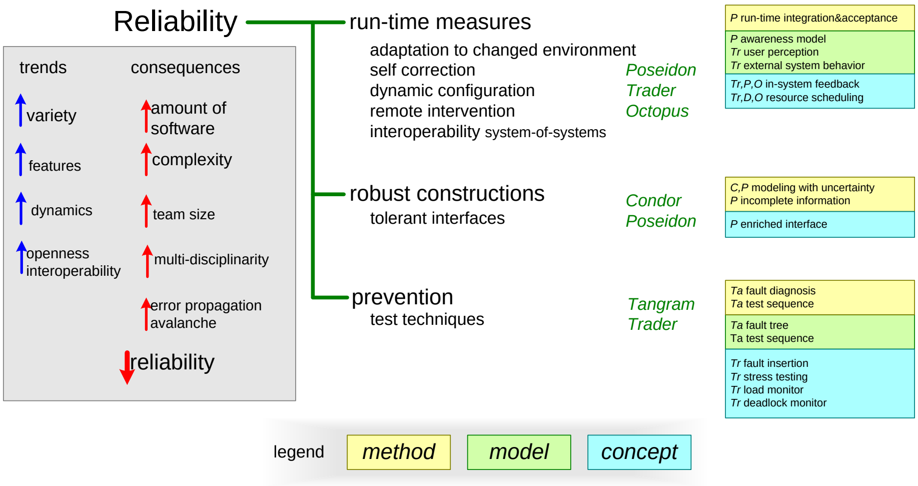


Figure 7: Example of ESI research agenda

The research agenda needs to be elaborated one step further to achieve the level as shown in the ESI research agenda example in Figure 7.

As intermediate step we have made an inventory of potential research subjects for the proposed agenda, as shown in Figures 8 and 9.

We will use the so-called *Industry-as-Laboratory* research model as shown in Figure 10. The research team builds an intimate relationship with an industrial product creation team. This relationship must be mutually beneficial. The research team gets inspiration from real industrial challenges, and at the same time it gets a means to verify research results in industrial settings. The industrial partner gets inspiration from intermediate results, and is continuously challenged by unbiased, creative, and critical people.

For the Buskerud situation Figure 11 shows that research projects will initially target one specific domain. For academic purposes and for transfer purposes we will need to generalize and consolidate the single domain research results. In practice sufficient domain specific research is a prerequisite to make usable and valid generalizations.

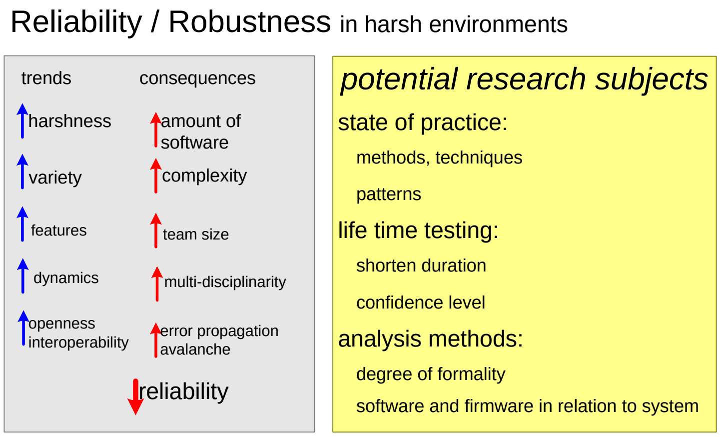


Figure 8: Buskerud Reliability / Robustness

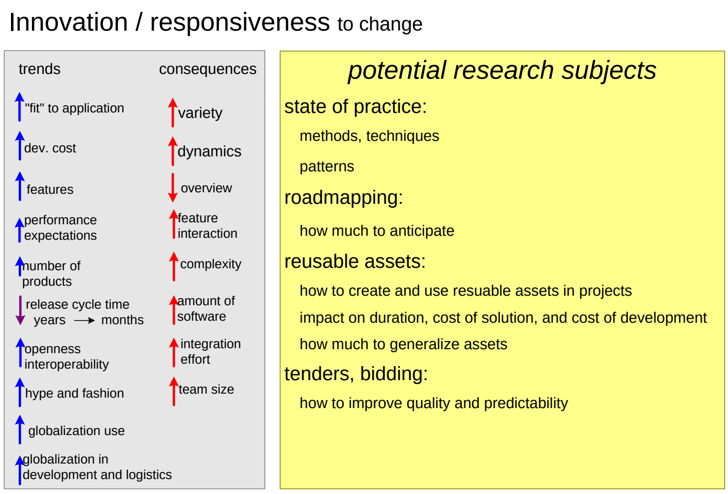


Figure 9: Buskerud Innovation / Responsiveness

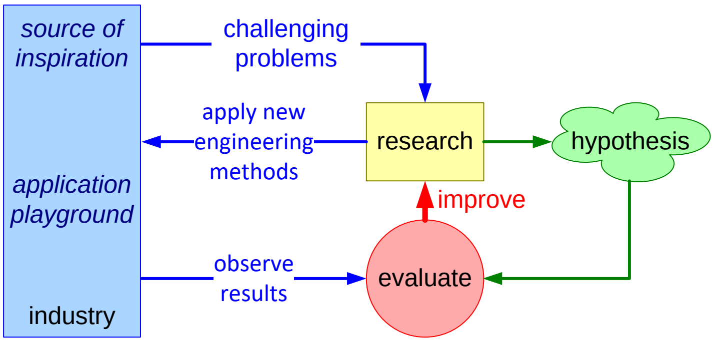


Figure 10: Industry as Laboratory

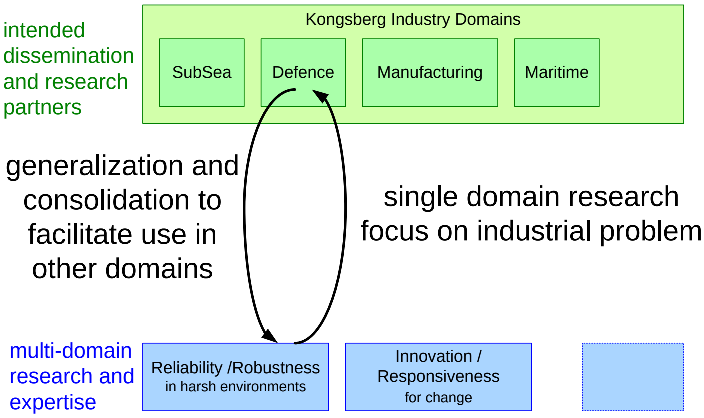


Figure 11: Industry as Laboratory (2)

3 Educational Curriculum

The Systems Engineering education is provided in different models:

industry master is a masters level education dirctly following a bachelor in engineering. Part of the program is executed as *industry-as-laboratory*: students are working part-time in industry to learn and to apply systems engineering in industrial practice.

part-time master is a masters education for employees with working experience who do the masters education as part-time education. The study program is identical to industry master, however the timing depends more on the available study time.

life-long education is based on regular courses with the same knowledge as the masters programs. However, no masters degree is provided. Development of *Systems Engineering* courses is possible.

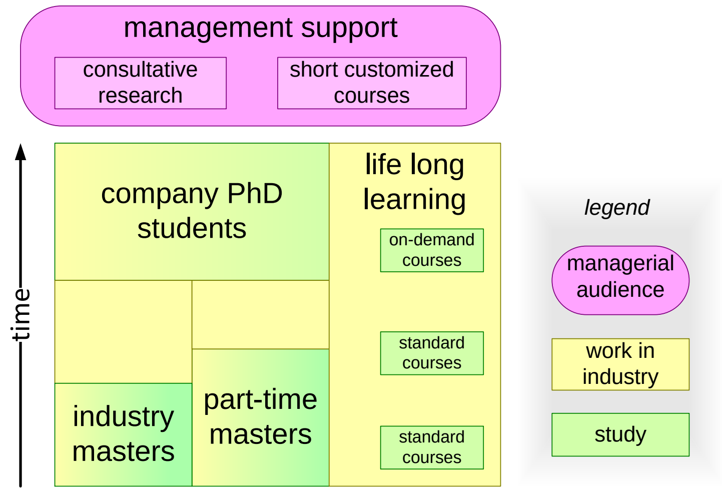


Figure 12: Buskerud SE Educational Options

Figure 12 shows these different educational options. It also shows the possibility for *company PhD students* as next step of education after the masters degree. Short customized courses are avaliable to support management in *Systems Engineering* and in the SE-staffing. In practice we observe the problem that educated Systems Engineers are constrained in applying *Systems Engineering* because the environment does not know what to expect and how to benefit. These short courses address this issue. Consultative research is available to further support management in industry.

4 Acknowledgements

This research agenda is based on discussions with and inputs of: Halvor Austena, Gunnar Berge, Merete Faanes, and Rolf Qvennild. The agenda is further elaborated with inputs from representatives of Kongsberg industrial partners:

- Jan Kopperud, Kongsberg Group
- Espen Gaarder, Kongsberg Maritime
- Morten Gunnerud, Kongsberg Automotive
- Andreas Thorvaldsen, Volvo Aero Norway
- Stein Solberg, Dresser Rand
- Tore Faanes, FMC Technology
- Knut Nordgaard, Devotek
- Arve Johansen, Kongsberg Automotive
- Kjetil R. Myhra, Kongsberg Defence and Aerospace

References

[1] Gerrit Muller. The system architecture homepage. `http://www.gaudisite.nl/index.html`, 1999.

History

Version: 1.4, date: August 3, 2010 changed by: Gerrit Muller

- adapted title to "Buskerud University College: Program Systems Engineering"

Version: 1.3, date: June 5, 2008 changed by: Gerrit Muller

- added research master plan to presentation (not yet in article)

Version: 1.2, date: November 14, 2007 changed by: Gerrit Muller

- added modeling and analysis to SE skills

Version: 1.1, date: November 10, 2007 changed by: Gerrit Muller

- added names to acknowledgements
- added educational options
- added introductory trends slide
- repaired references

Version: 1.0, date: November 10, 2007 changed by: Gerrit Muller

- added pyramid
- created slides with specific potential Buskerud research subjects
- created slide to explain System Engineering position
- added text for the positioning of SE and Buskerud
- added text for the research agenda
- chose logo

- increased status to preliminary draft

Version: 0.2, date: October 18, 2007 changed by: Gerrit Muller

- minor updates
- changed footer logo to Buskerud logo

Version: 0.1, date: October 12, 2007 changed by: Gerrit Muller

- Changed agility into responsiveness

Version: 0, date: September 24, 2007 changed by: Gerrit Muller

- Created, no changelog yet