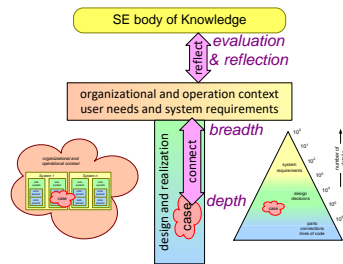# Systems Engineering Master Project

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Abstract

The master study Systems Engineering is completed by performing a master project. This document describes objectives and guidelines for the project and the resulting paper or report.

1 Introduction

Students must do a research project as part of the Systems Engineering master education at Buskerud University College. The project is performed in the last semester of the study. The goals of the project, further elaborated in section 2, are to apply systems engineering techniques in practice and to do actual research.

The master project is 6 months full time work, resulting in 30 ECTS.

This document is mostly applicable for many master studies, although this document described the specific situation of Systems Engineering at BUC.

2 Project Goals and Positioning

Apply SE methods, techniques, and concepts in practice
and evaluate and reflect on its application,
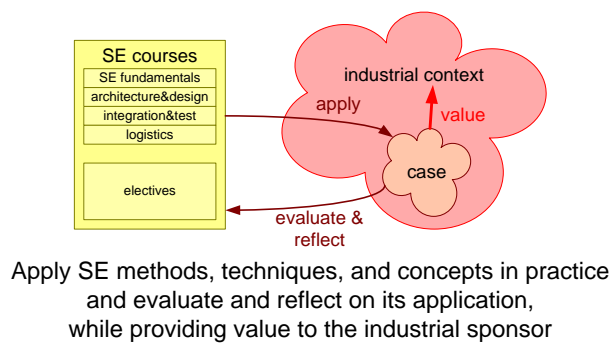while providing value to the industrial sponsor

Figure 1: Objectives of Masters Thesis Project

The main goals of the master project, shown in Figure 1, are:

- the students have to prove again their professional competence and the acquired command of the systems engineering discipline by applying it to a selected problem;

- the selected problem has to be relevant in the context of the company in which the student works, so that knowledge is truly put into practice.

- to facilitate the students to make the step from "just applying" to "critical reflection".

- to verify that students are capable to operate at academic level.

A good paper has a clear line of reasoning starting with a trigger or problem statement, finally resulting in a clear conclusion. The paper has to provdie such line of reasoning specifically for the case from company perspective and more generic for the chosen method/technique/topic from Body of Knowledge (BoK)

perspective. The scope of the case and the BoK contribution and their significance play a significant role in grading. Finally, the paper needs to provide a clear academic justification for the research approach (the research methodology), discussing aspects such as validity.
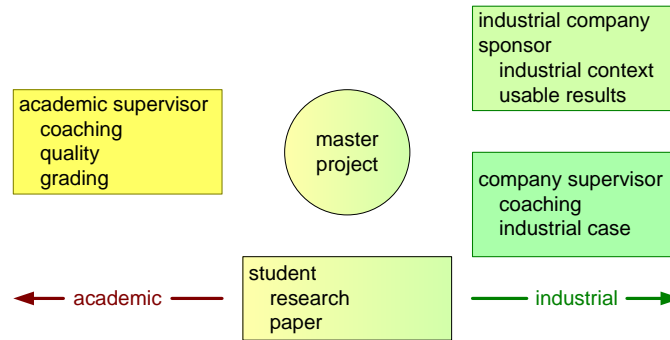

Figure 2: Stakeholders of the Thesis Project

The project has multiple stakeholders with different concerns. Figure 2 shows at the right side the industrial stakeholders: the sponsor who provides the industrial context and who expects usable results, and the supervisor who does the daily coaching and who is involved closely with the industrial case. At the left hand side the academic stakeholders are shown: the SIT professor responsible for the quality and the grading, and the BUC professor who does the daily academic coaching and who aligns the project with the BUC research agenda. In the middle the master student is shown as remaining stakeholder, doing the research project that must result in a paper.

What methods, techniques, tools, concepts	Systems Engineering
What (sub)systems, releases, functions, qualities, aspects, disciplines, technologies	industrial
What timing of activities and deliverables	planning
What resources (student time, means, advisors)	planning
What approach, criteria	research

Figure 3: Scoping is Crucial

The industrial environment is broad and complex, and the field of Systems Engineering is also quite broad. Scoping of the project is a crucial success factor. It is difficult to reach a specific result with some substance in a half year, if the scope of the project is broad.

Figure 3 shows that the project can be scoped in multiple dimensions. Core part of the scoping is what Systems Engineering methods and techniques will be researched and what industrial case will be used. The scope can be further fine-tuned by the project planning, resources and research method.

The student has to select what methods, techniques, tools or concepts will be applied, to scope the Systems Engineering content. Note that in general several methods and techniques will be used in the case, however, the focus of the research itself has to be more narrow. For example, in the industrial case requirements, selection matrices, functional models, use cases, and activity diagrams might be used, while the focus of the research is only on selection matrices.

The industrial supervisor and the student have to scope the case, by determining what component(s), what subsystem(s), what function(s), what qualities, aspects, disciplines and technologies belong to the case. For example, the case could be the control engineering part of the motion control component in the positioning subsystem.
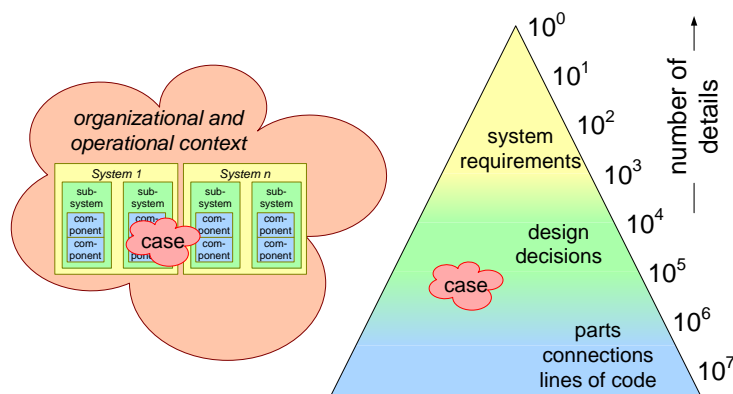

Figure 4: Case Positioning

We have described the case positioning above in several dimensions. Figure 4 adds one more perspective on the case positioning: the level of abstraction or the amount of details taken into account.

Typical cases that have been scoped to fit the project needs address only part of the system, making the case somewhat remote from the system itself and the customer needs. Figure 5 shows that the breadth of Systems Engineering requires the student to link the case to the system requirements, the user needs and the organizational and operational contexts. The research part of the project is to reflect on this depth and breadth interaction in relation to the Systems Engineering Body of Knowledge.

Finally, Figure 6 shows that the industrial and academic interests are different: industrial interests are primarily to address the case, using Systems Engineering
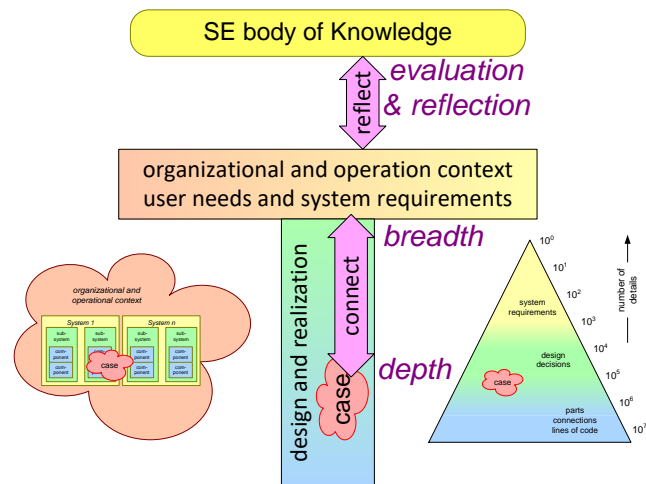
Figure 5: Depth, Breadth and Reflection

knowledge as means, while the academic interest is to extend and solidify the Systems Engineering Body of Knowledge, using the case as means.

The research projects must also fit in the interests of the academic supervisor. The NISE Research Agenda, shown in Figure 7 from [2], provides some direction to select the Systems Engineering content and industrial case to fit in the NISE interests.

Figure 8 shows how the master projects of the first generations of master students map on the research agenda. The research agenda is shown different: as a Venn diagram. Every small rectangular box with two letter initials represents the position of that specific master project. At the bottom of the diagram it is shown that every individual project is a very small contribution to the research area. However, the combination of many small projects helps to get a better understanding of the research field, to see patterns, and to start validation across projects and domains.

Consequence of this approach is that the playing field is evolving. Tis emans that the yardstick for grading changes gradually. Newer projects build on previous projects.
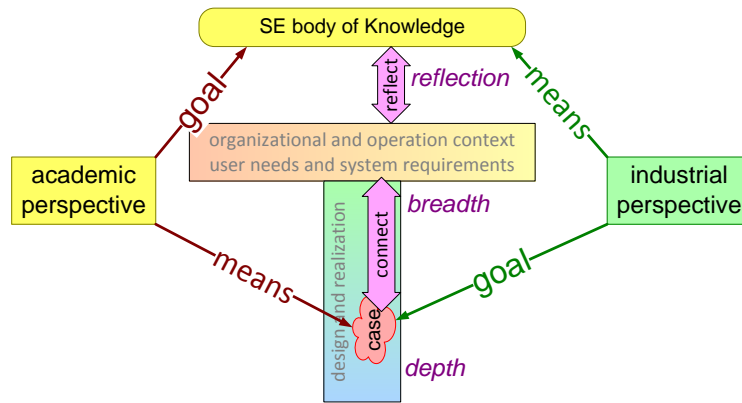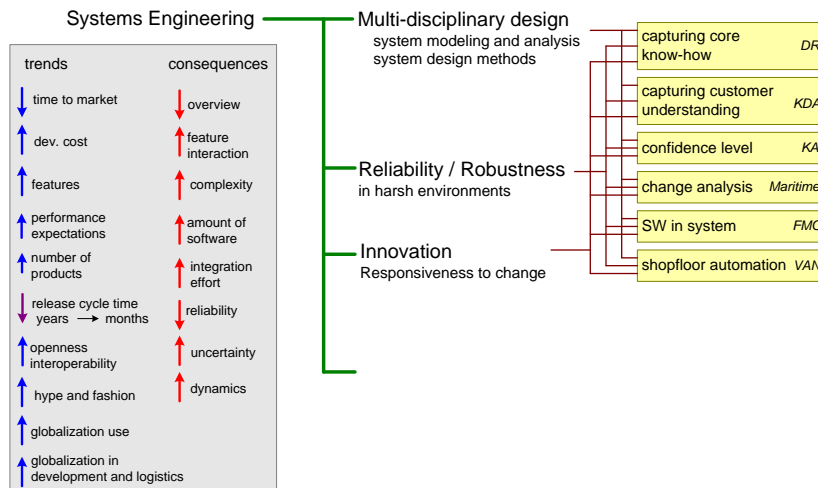
Figure 6: Difference Academic and Industrial Goals
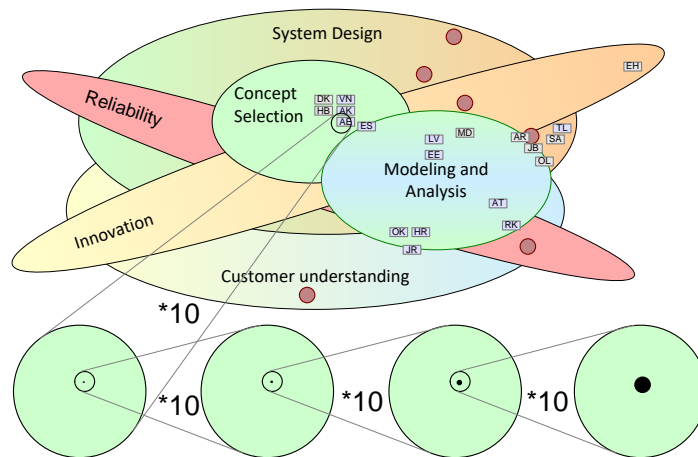

Figure 7: Buskerud Research Agenda

Figure 8: Mapping Master Projects on the Research Agenda

3   Preparing and Performing the project

Figure 9 shows the entire process of preparing and executing the project. Figure 10 visualizes the process on a timeline. The first steps are to pick the subject for the project and to secure the advisors. Then the subject can be scoped, as described in Section 2.
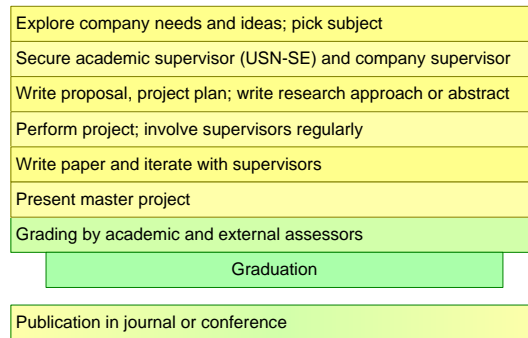

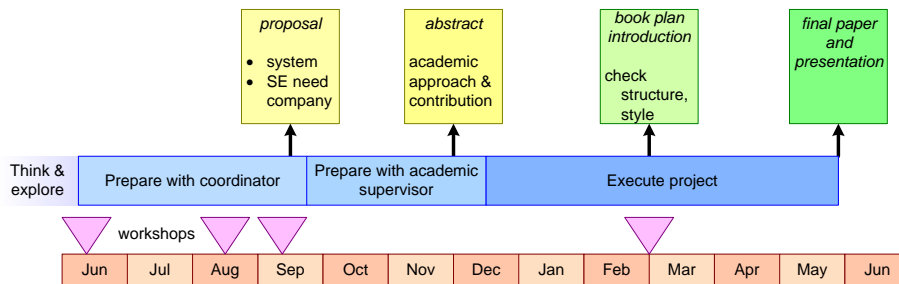Figure 9: Process of the Master Project

Figure 10: Timeline of the Master Project

The project is described in three single page deliverables:

proposal describing the project, the case, and the value for the industrial sponsor

plan showing the project time-line, activities, milestones, and their relations

abstract of the paper to delivered at the end of the project

[3] provides more background information on shaping this type of multi-disciplinary projects.

Figure 11 shows the main milestones in this process. The milestone dates are an indication. The master project coordinator will communicate the exact dates.
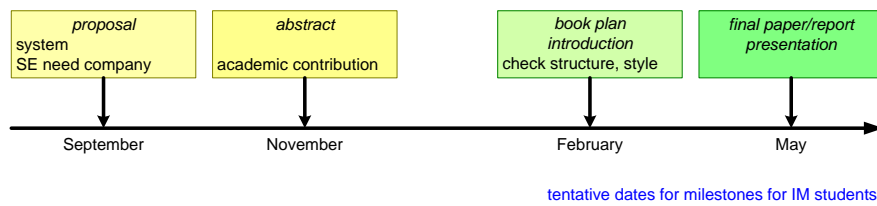
Figure 11: Master Project Milestones

Student and academic supervisor have to agree on the abstract before the project itself can be started.
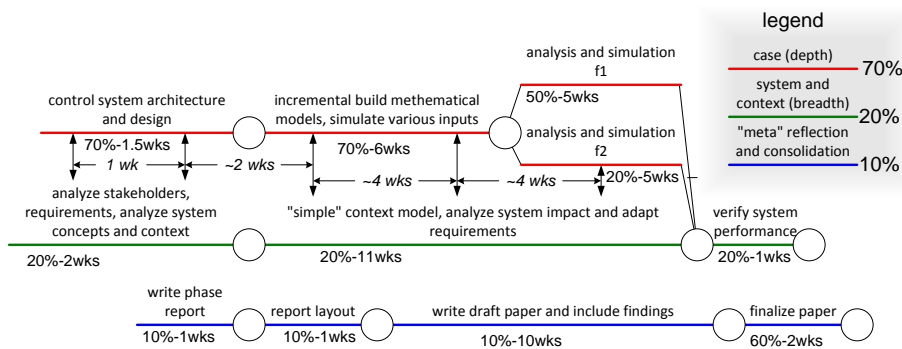

Figure 12: Plan: Simple PERT Diagram

We recommend to draw a simple and straightforward PERT plan [4]. An typical example for this type of projects is shown in Figure 12. In this plan we show the three main topics shown in Figure 5: the case specifics, the system and its context, and the reflection and research activities. Note that all these activities run concurrently. We recommend to use time-boxes of hours to days to manage this concurrency. The plan also shows that typically most time is spend in the case itself (about 70%), less time is spend on the system and its context (about 20%), and the time of actually reflecting and writing (the final delivery) is only about 10%.

After scoping the project, and discussing it with the advisors, the next challenge is to write the abstract of the paper before the actual project start. Writing of the abstract forces the student to think and to be sharp about the research project its goal and the expected outcome. Figure 13 shows a quote from Prof Pennotti from SIT explaining what constitutes a good abstract.

The challenge in writing such abstract is that the student has to take the future perspective: imagining that the project has been finished. Figure 14 illustrates this "time machine" that is needed to write the abstract. Note that the actual abstract
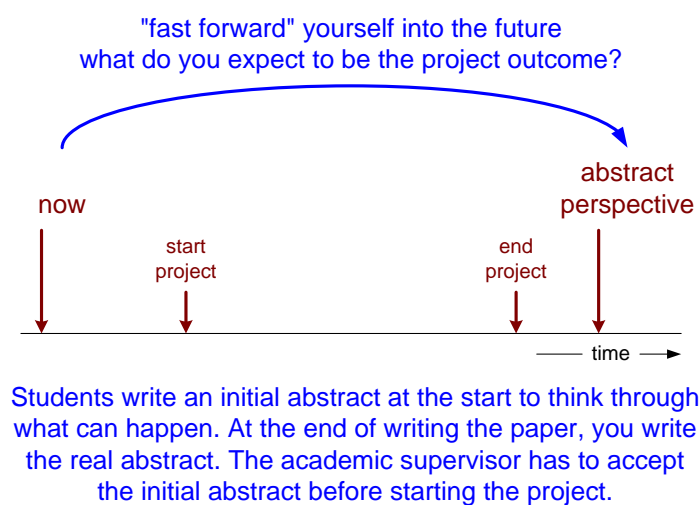
Figure 13: Abstract

Figure 14: Needed: Time Machine

in the final paper probably will be adapted to fit the actual findings. The students don' have to fear that the abstract is fixed after writing this initial version.

Once the project is approved the project execution can begin. Figure 15 gives a number of recommendation for the execution of the project:

maintain a project log during the entire project execution, from the early beginning onwards:

- Make bibliographic notes of papers, books, and other documentation sources.

- Store all "raw" data obtained by interviews, measurements, or any other project activities.

- Archive intermediate results, such as presentations.

maintain a project log	data, findings documents references
keep supervisors involved	regular presentations regular meetings
time box and iterate	case system and context reflection and consolidation
early feedback on paper	start writing early elicit feedback early work incremental

Figure 15: Project Execution

keep advisors involved by organizing regular meetings and presenting regularly

time box and iterate the different levels of activities in the project:

- the case work itself (depth)

- the system, user needs, and the organizational and operational contexts (breadth)

- reflection and consolidation

elicit early feedback on the paper , start writing parts of the paper early and ask for feedback early and frequently from different stakeholders. Create the paper in an incremental way.

1. Explanation of the subject; what is the goal of the project? 2. Positioning of the subject in the academic context and literature; what does this paper add to the Body of Knowledge? 3. How is the project performed, what has been done. 4. Evaluation of the project, reflection on the results and the project itself. 5. Paper should be submittable to a refereed conference or to a journal; the academic supervisor may accept a report as well.

Figure 16: Publishable Paper

The final deliverable of the project and the main input for grading is the paper or the report. The goal is to produce a paper that can be published at a conference or in a journal. Figure 16 shows what should be the content of the paper.

1. Clearly introduce the problem that the manuscript is discussing/ addressing,

2. Discuss the problem background. That is, discuss the research that has been previously conducted by you or others in the field (or related fields) to solve/address the same or similar problem,

3. Develop a succinct argument for the methods or ideas proposed in your manuscript,

4. Present a clear and understandable justification of why the proposed methods or ideas contribute to a superior or different solution to the problem. A clear statement of your contributions is often crucial to reviewers. Clear specify this when possible. And finally,

5. Discuss the likely future directions of the research being conducted by you (your group).

http://www.stevens-tech.edu/ses/documents/fileadmin/documents/pdf/SE_Master_Project_Guidelines.pdf

Figure 17: Stevens Guidelines for Paper

At the end of the master project, the student presents his master project. Figure 18 shows the set-up of this presentation.

4   Publication

We intend to publish the paper in a journal or at a conference. The student is the first author of the paper, the academic supervisor(s) are second and third author. Publication takes time and practically takes place after graduation. Figure 19 shows the publication process.

If a third party is involved, e.g. a customer or supplier, then ask the third party to agree with publication procedure:

`http://www.gaudisite.nl/BuskerudSEpublicationProcedureSlides. pdf`, and ask who will be reviewer for the third party.

5   Practicalities

We do have a set of conventions to more easily manage the stream of artifacts produced during the preparation and the execution of the project, see Figure 20.

We assume that all communication of artifacts takes place electronically. All filenames should follow the conventions shown in Figure 20, the concatenation of the abbreviation *SEMP* (Systems Engineering Master Project), the *students name* (first name, family name), the *subject* (e.g. proposal, abstract, plan, presentation, paper), *dot*, *version*, *dot extension*.

The file type should be reasonably standard, e.g. pdf, jpeg, or one of the file formats that can be read both by Microsoft Office as well as OpenOffice (doc, docx,
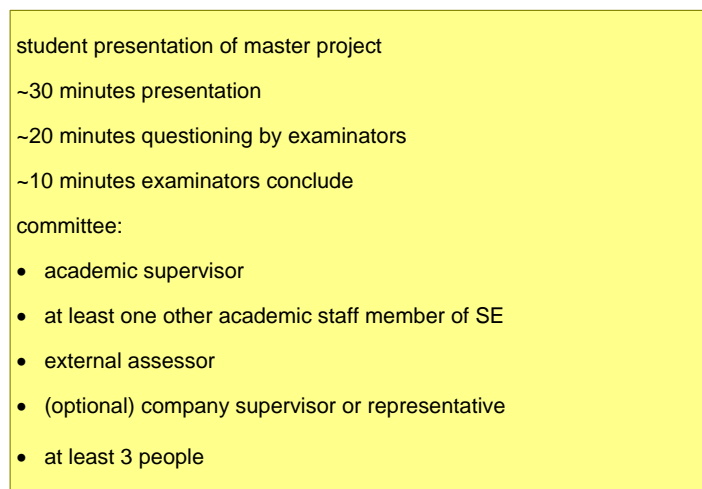
Figure 18: Final Presentation at the end of the project

xls, xlsx, ppt, pptx). Exotic formats, such as Microsoft Projects, only after approval by the advisors.

Submissions have to be send to Gerrit Muller. The subject should again contain the abbreviation SEMP and the subject.

6 Acknowledgements

This document has been written with inputs from Stevens Institute, especially Mike Pennotti, and from Gunnar Berge. The first cohorts of students doing their master project helped to shape this document.

7 Links

Figure 21 provides links to websites with more relevant information.

References

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

[2] Gerrit Muller. Buskerud university program systems engineering. `http://www.gaudisite.nl/BuskerudAgendaPaper.pdf`, 2008.

Figure 19: Publication Process

[3] Gerrit Muller. A multi-disciplinary research approach, illustrated by the boderc project. `http://www.gaudisite.nl/MultiDisciplinaryResearchApproachPaper.pdf`, 2008.

[4] NetMBA.com. Topics in project management: PERT. `http://www.netmba.com/operations/project/pert/`, 2007.

History

Version: 1.8, date: March 1, 2018 changed by: Gerrit Muller
- added SETPtimeLineSEMP

Version: 1.7, date: April 13, 2016 changed by: Gerrit Muller
- removed criteria
- added presentation to SETPprocess
- made external assessor mandatory at presentation
- adapted submission instructions
- remved dead link to Stevens guidelines

Version: 1.6, date: June 8, 2015 changed by: Gerrit Muller
- added criteria
- removed research agenda

Version: 1.5, date: September 8, 2014 changed by: Gerrit Muller
- links for September workshop

Version: 1.4, date: March 18, 2014 changed by: Gerrit Muller
- added milestones
- added brief text about presentation

Version: 1.3, date: June 12, 2013 changed by: Gerrit Muller
- added formalized goals
- adapted the text in the paper accordingly
- updated stakeholders figure
- used term supervisor more consistently
- explained the goal of the initial abstract
- added final presentation
- updated links

Version: 1.2, date: August 24, 2012 changed by: Gerrit Muller
- slide with links

Version: 1.1, date: August 20, 2010 changed by: Gerrit Muller

Submission instructions

use for all preparation deliverables the following conventions:

filename: SEMP <your name> <subject>.<version>.<extension>

    e.g. SEMP John Student abstract.2.doc

where subject = {proposal | abstract | plan | presentation | paper | ...}

email to: <gerrit . muller@ gmail . com>

subject: SEMP <subject>

"standard" file types preferred, e.g. pdf, jpg, doc, xls, ppt

Figure 20: Conventions for Submitting Project Deliverables, in the preparation phase

- added publication to process
- added slide about publication
- added third party slide
- removed alternative project report
- added map of research projects
- removed paragraph in introduction about the relation Stevens and BUC
- changed status to concept

Version: 1.0, date: February 3, 2009 changed by: Gerrit Muller
- made a paper version
- changed status to draft

Version: 0.3, date: February 2, 2009 changed by: Gerrit Muller
- added submission instructions

Version: 0.2, date: January 29, 2009 changed by: Gerrit Muller
- added figures to explain multiple levels
- added PET plan
- added abstract explanation
- changed title

Version: 0.1, date: January 26, 2009 changed by: Gerrit Muller
- added figures to position case and project work

Version: 0, date: May 23, 2008 changed by: Gerrit Muller
- Created, no changelog yet

workshop 1 in June
   Master Project Description: http://www.gaudisite.nl/SEthesisProjectPaper.pdf
workshop 2 in August
   Systems Engineering Research Methods: http://www.gaudisite.nl/SEresearchMethodsSlides.pdf
workshop 3 in September
   Master Project; Writing an Abstract: http://www.gaudisite.nl/MasterProjectWritingAnAbstract.pdf
   Master Project; Execution Phase: http://www.gaudisite.nl/MasterProjectProjectExecution.pdf
Publication procedure: http://www.gaudisite.nl/BuskerudSEpublicationProcedureSlides.pdf
Guidelines for visualizations: http://www.gaudisite.nl/VisualizationGuidelinesSlides.pdf
Validation of Systems Engineering Methods and Techniques in Industry
   http://www.gaudisite.nl/CSER2012_Muller_validationSEinIndustry.pdf
Systems Engineering Research Methods (paper)
   http://www.gaudisite.nl/CSER2013_Muller_SEresearchMethods.pdf
Systems Engineering Research Validation http://www.gaudisite.nl/SEresearchValidationPaper.pdf
Published Master Project papers: http://www.gaudisite.nl/MasterProjectPapers.html
Workshop Academic Writing http://www.gaudisite.nl/RPacademicWritingSlides.pdf

Figure 21: Links for more information