

# Systems Engineering Course Research Methods; all slides

by *Gerrit Muller*

USN-SE

## Abstract

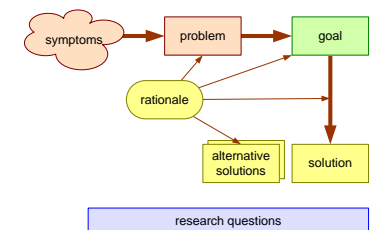
This course teaches research methods for systems engineering and related disciplines, such as industrial economy, engineering management, innovation, and technology management. This field of research needs research methods combining the traditional scientific methods ("hard") and methods from social sciences ("soft").

The course prepares students for their master thesis.

## Distribution

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# Systems Engineering Course Research Methods; Information

by *Gerrit Muller*     University of South-Eastern Norway-NISE

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## Abstract

This module provides information about the course, such as the schedule.

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logo

TBD

This course is a joint development of

Kristin Falk

Satya Kokkula

Elisabet Syverud

and Gerrit Muller

# Research Methods Course Pre-assignment

---

- Determine a topic for the master project
- Position the topic in its context (e.g. in your company, in ongoing projects)
- Discuss the topic with its stakeholders
- Try to formulate the line of reasoning:
  - problem, goal, envisioned solution, rationale, open research questions

# Course Schedule

	day 1	day 2	day 3	day 4	day 5
9:00	5 step framework, meta levels	literature why, what, how	homework	re-iterate meta-levels	what is a good paper?
	line-of-reasoning	search applicable literature	data collection, analysis	<i>re-iterate research questions how to answer them?</i>	write an initial abstract
	break		Analysis of Survey data		
10:00	specific initial problem statement	break	break	break	break
	problem exploration	practical search techniques	Relate Data and RQs	data validity, bias	discussion, what is the flow in the paper?
11:00	break	refine search	research methods	discuss validity of the data analysis	annotate the book plan with content and scope keywords
	framing the problem, prepare interviews		<i>re-iterate research design</i>	lunch	lunch
12:00	lunch	lunch	reflection and discussion		
	reflection and discussion	library resources	reflection and discussion	project execution and planning	practicalities, e.g. visualizations, citations
13:00	research questions	reflection and discussion	statistics	break	break
	break	break	Statistical Analysis	make initial project execution plan (PERT)	make a research design diagram
	formulate initial research questions	research design how, what to look for			
14:00	break	initial research design	break	academic writing, book plan	master project supervision and assessment
	feasibility of study	break			
	reflection and discussion	homework	ethics, plagiarism, privacy, confidentiality, regulations	homework	homework
15:00		reflection and discussion	reflection and discussion	reflection and discussion	reflection and discussion
16:00					
homework	<ul style="list-style-type: none"><li>initial interview and/or survey</li><li>initial problem analysis</li><li>literature survey Body of Knowledge</li><li>search secondary data sources</li><li>read Research Methods paper</li><li>elaborate research design</li></ul>		<ul style="list-style-type: none"><li>continue literature survey</li><li>write critic of 2..3 papers</li><li>identify challenges and risks in problem definition</li><li>make research design more concrete</li><li>make book plan for the course paper</li></ul>		<ul style="list-style-type: none"><li>write a course paper, ca 15 pages</li><li>line of reasoning</li><li>literature survey</li><li>research design</li><li>execution plan</li><li>book plan of final paper</li></ul>
	<div><div>30%</div><div>60%</div><div>10%</div></div>		<div><div>50%</div><div>15%</div><div>30%</div><div>5%</div></div>		

# Systems Engineering Course Research Methods; Framework

by *Gerrit Muller* USN-SE

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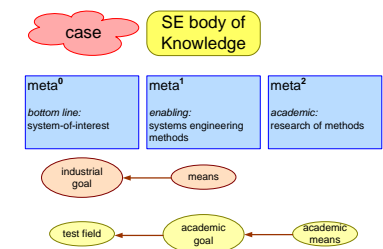
## Abstract

This module shows a framework for shaping and executing applied research, and offers guidelines for the various steps.

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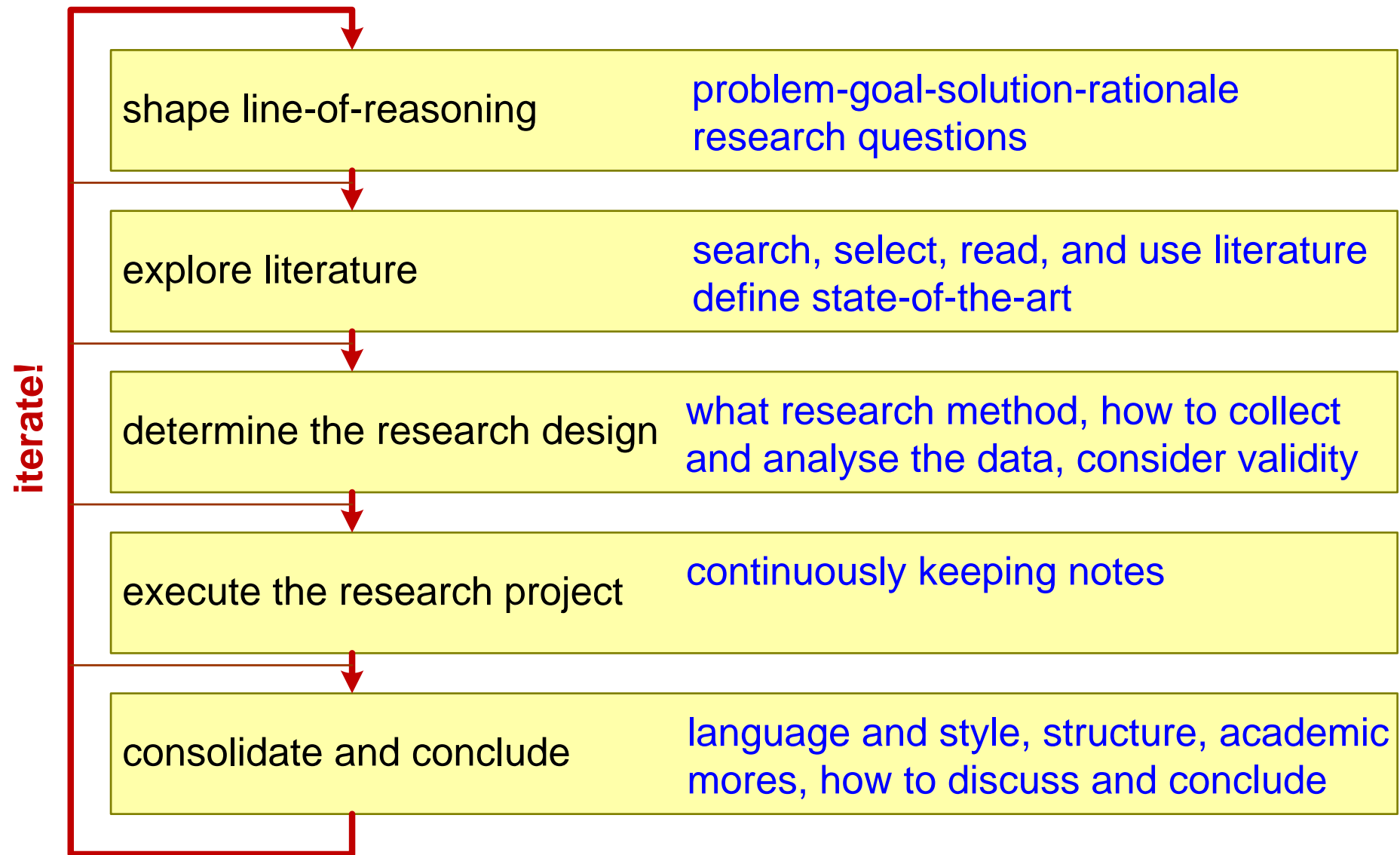
Kristin Falk

Satya Kokkula

Elisabet Syverud

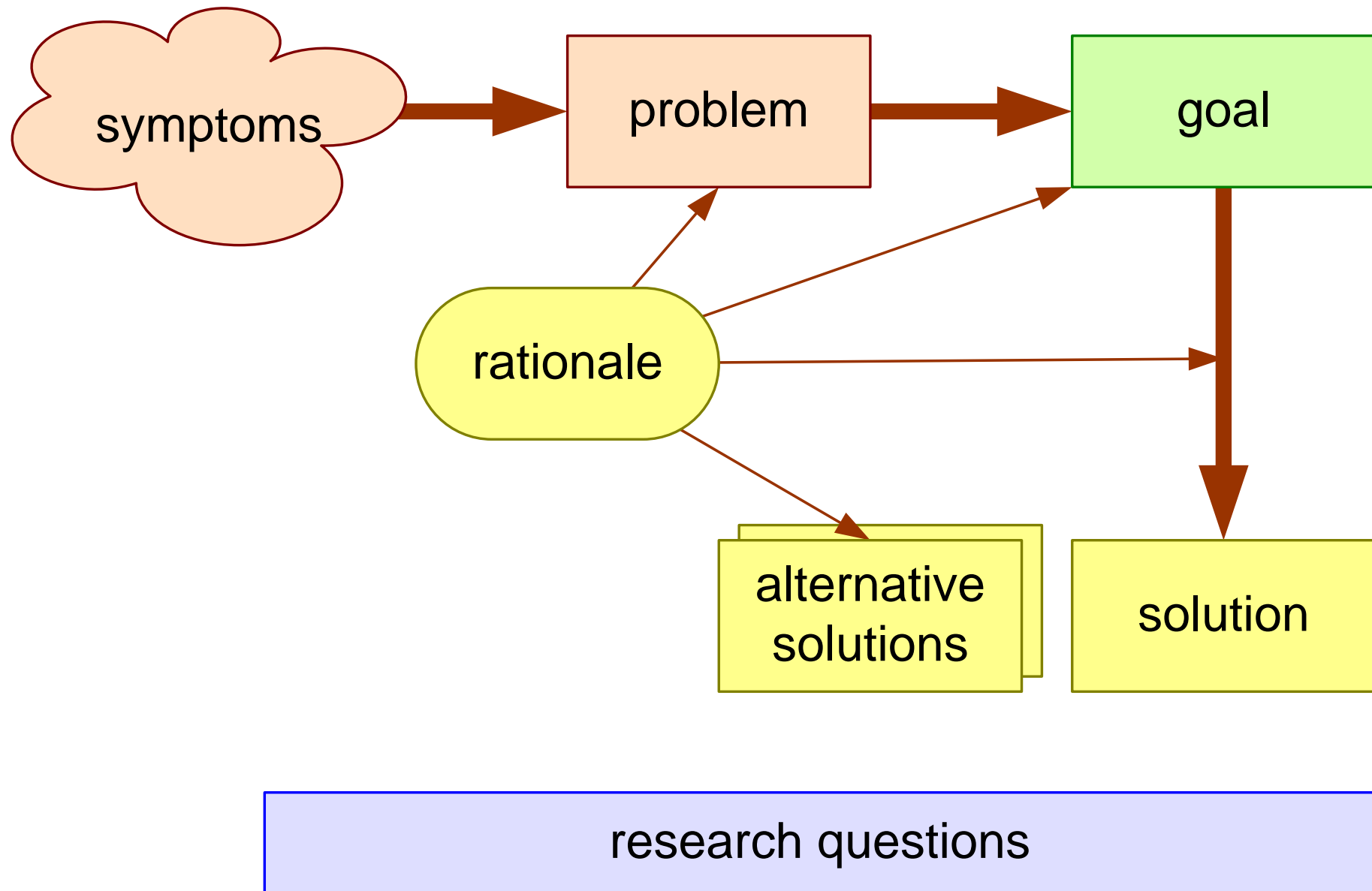
and Gerrit Muller

# Applied Research Framework

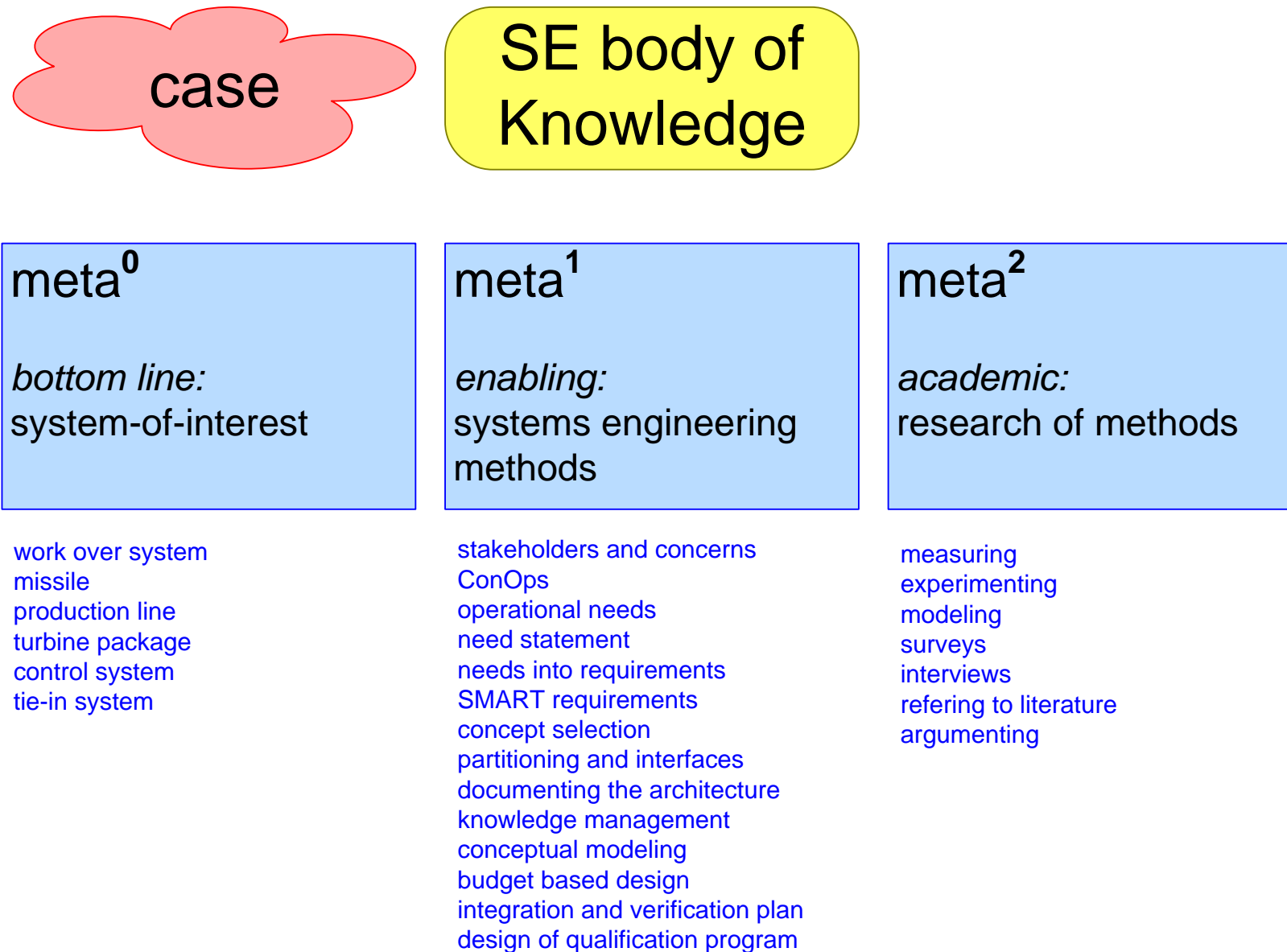




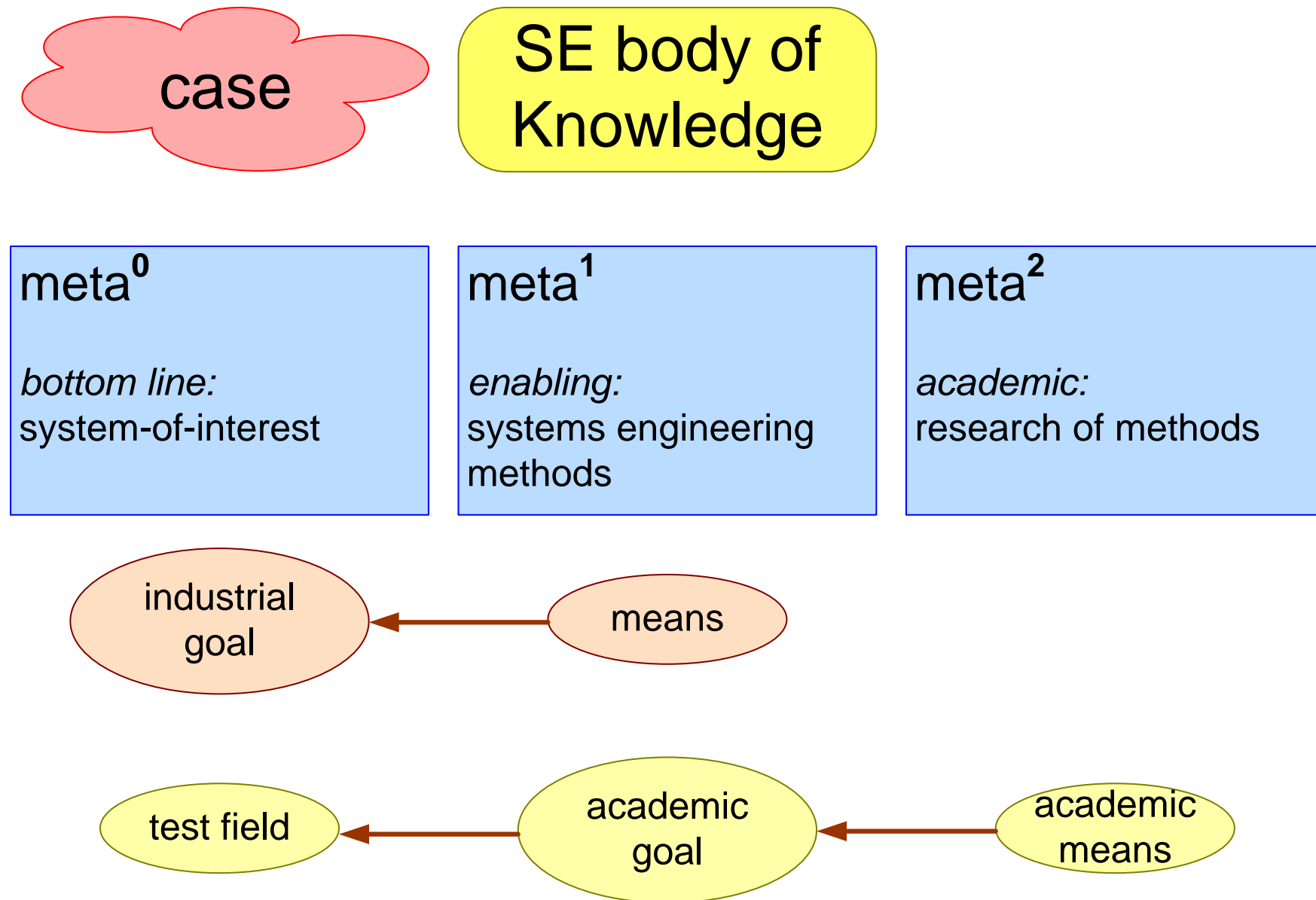
# Line of Reasoning



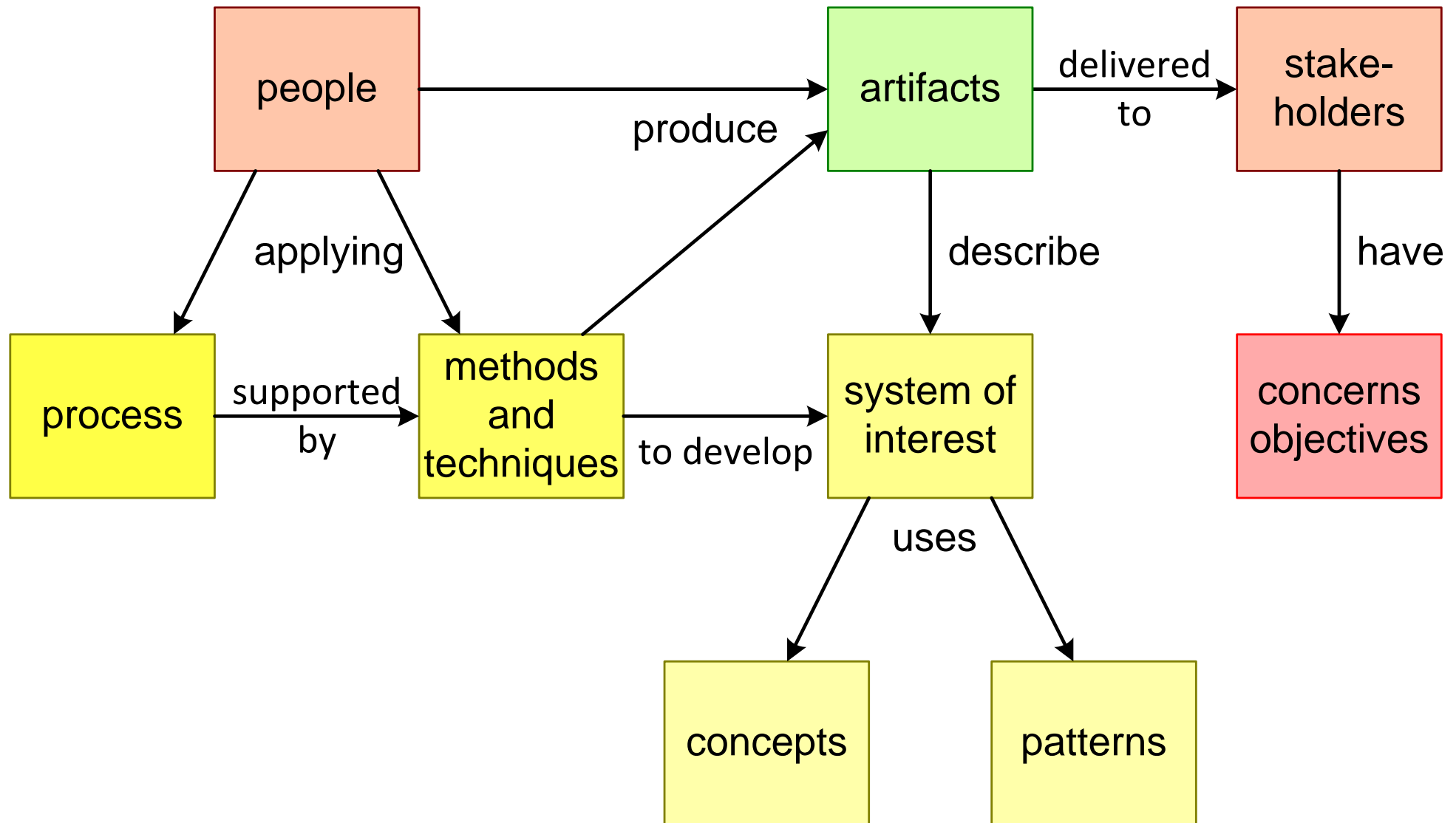
# Multiple Levels of Academic Abstraction



# Industrial versus Academic Perspective



# Research Context



# Some Terminology

---

**Formalisms** languages/syntax: for example, differential equations, timed or hybrid automata, finite state machines, et cetera

**Models** instantations of formalisms to understand, explore, optimize or verify specification or design

**Techniques** to get the required information from models:  
e.g. performance

**Methods** to provide guidelines how to use formalisms, create models, use techniques and apply tools

**Tools** to support efficient application of formalisms, techniques and methods

What is the actual *Study Load* of the courses in the program?

Courses of 7.5 ECTS should have a study load of 200 hours for nominal students.

If the study load is too little, then the study may fail audits

If the study load is too high, then we overload students

# Systems Engineering Course Research Methods; Problem Exploration

by *Gerrit Muller*    University of South-Eastern Norway-NISE

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## Abstract

Problem exploration requires first of all an exploration of the current situation. Next step is identifying weaknesses and issues in the current situation. Judgement of the severity of the consequences of the various weaknesses helps to get to the problem statement.

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TBD

This course is a joint development of

Kristin Falk

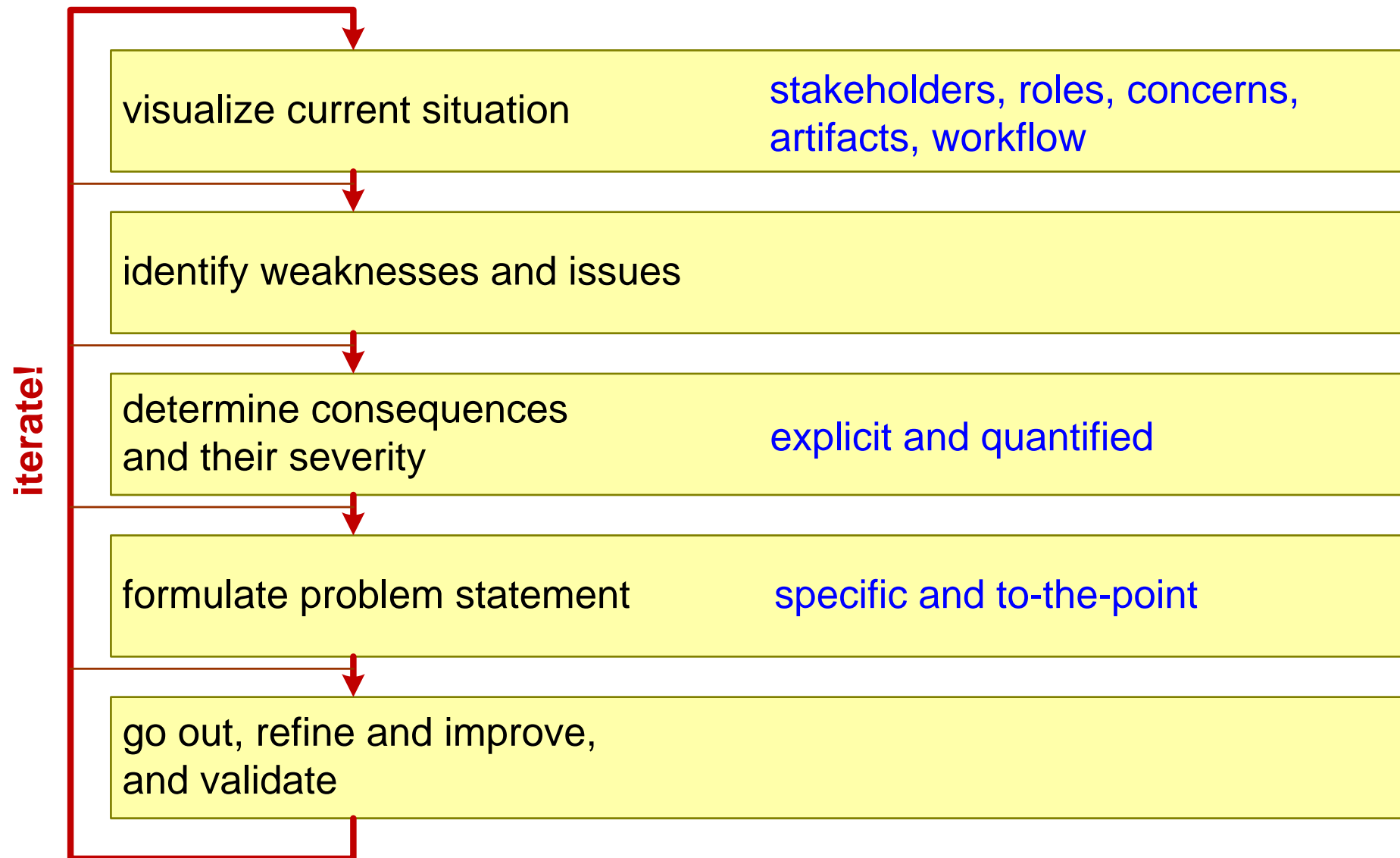
Satya Kokkula

Elisabet Syverud

and Gerrit Muller



# Problem Exploration Approach



# Literature why, what, how, and Practicalities

---

See presentation K.Falk [https://gaudisite.nl/SECRM\\_Falk\\_LiteratureWhyWhatHowAndPracticalities.pdf](https://gaudisite.nl/SECRM_Falk_LiteratureWhyWhatHowAndPracticalities.pdf)

# Systems Engineering Course Research Methods; Literature Search

by *Gerrit Muller* USN-SE

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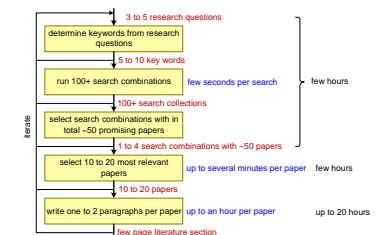
## Abstract

This presentation shows how to search and to select the relevant papers from the search hits.

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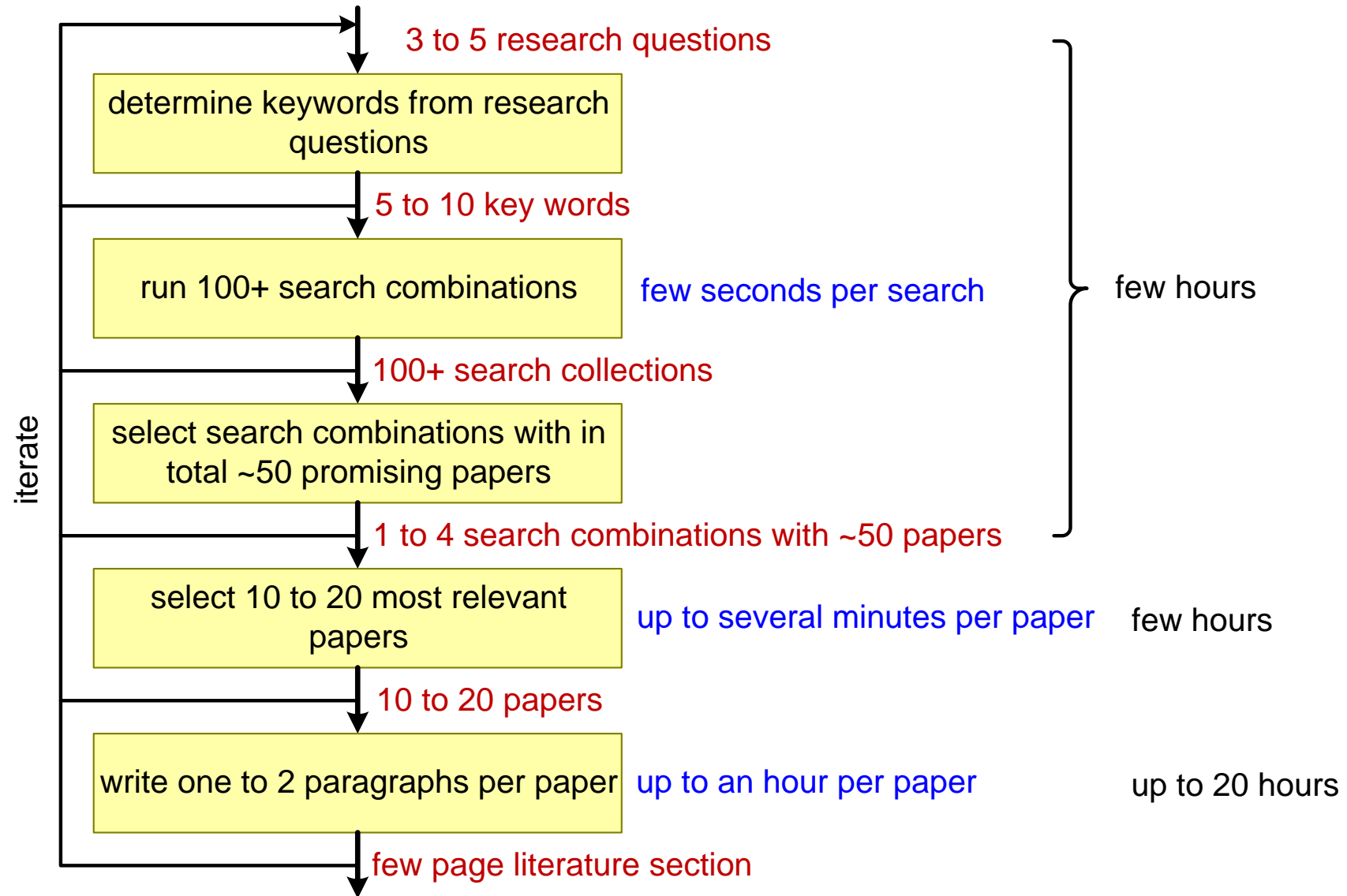
September 30, 2023  
status: preliminary  
draft  
version: 0



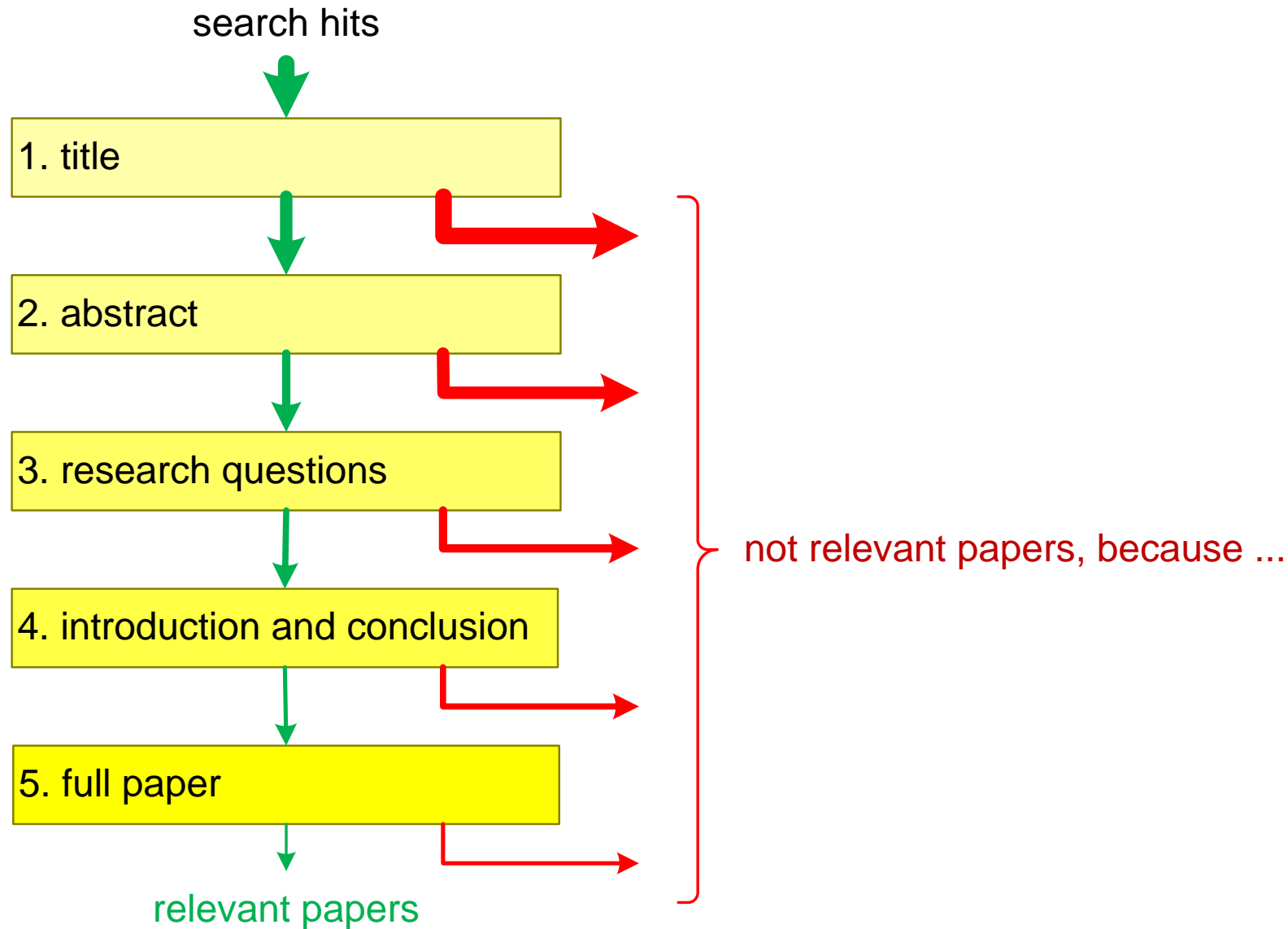
## Colophon

Kristin Falk's lecturing of literature review in the course Research Methods inspired the capturing of the literature search funnel

# Search Funnel



# Seleection Process to Find the Relevant Papers



# Research in Systems Architecting

by *Gerrit Muller*      University of South-Eastern Norway-NISE

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## Abstract

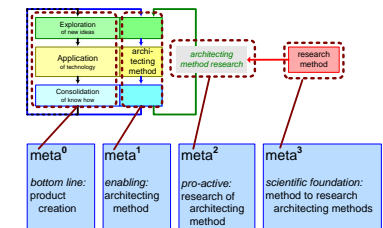
Researching architecting methods is a very abstract activity at a large distance from actual product creation. The relation between *product creation*, *architecting*, *architecting methods* and *architecting methods research* is shown.

The technology management cycle model is explained and mapped on product creation and research. This model is used as the basis to describe an “ideal” research method that is used to study architecting methods.

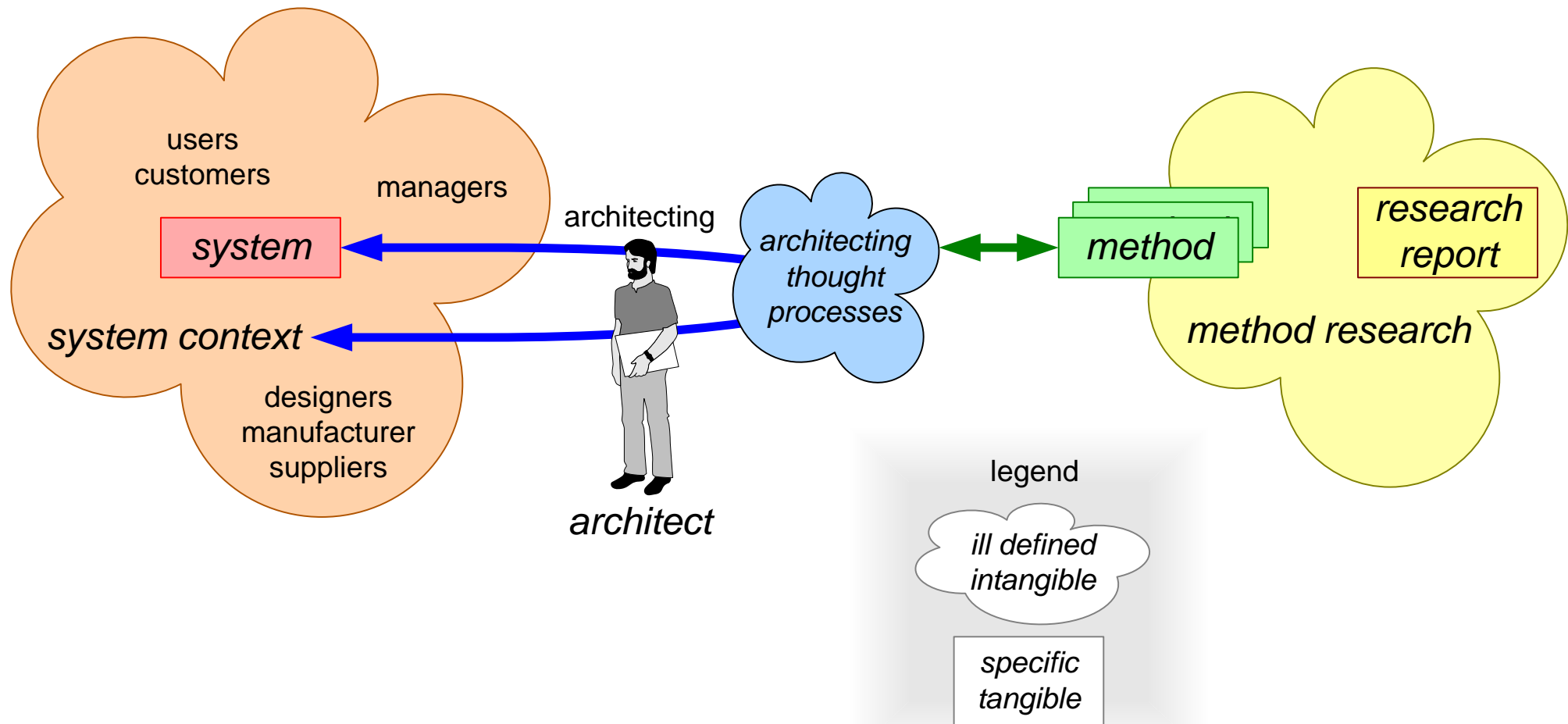
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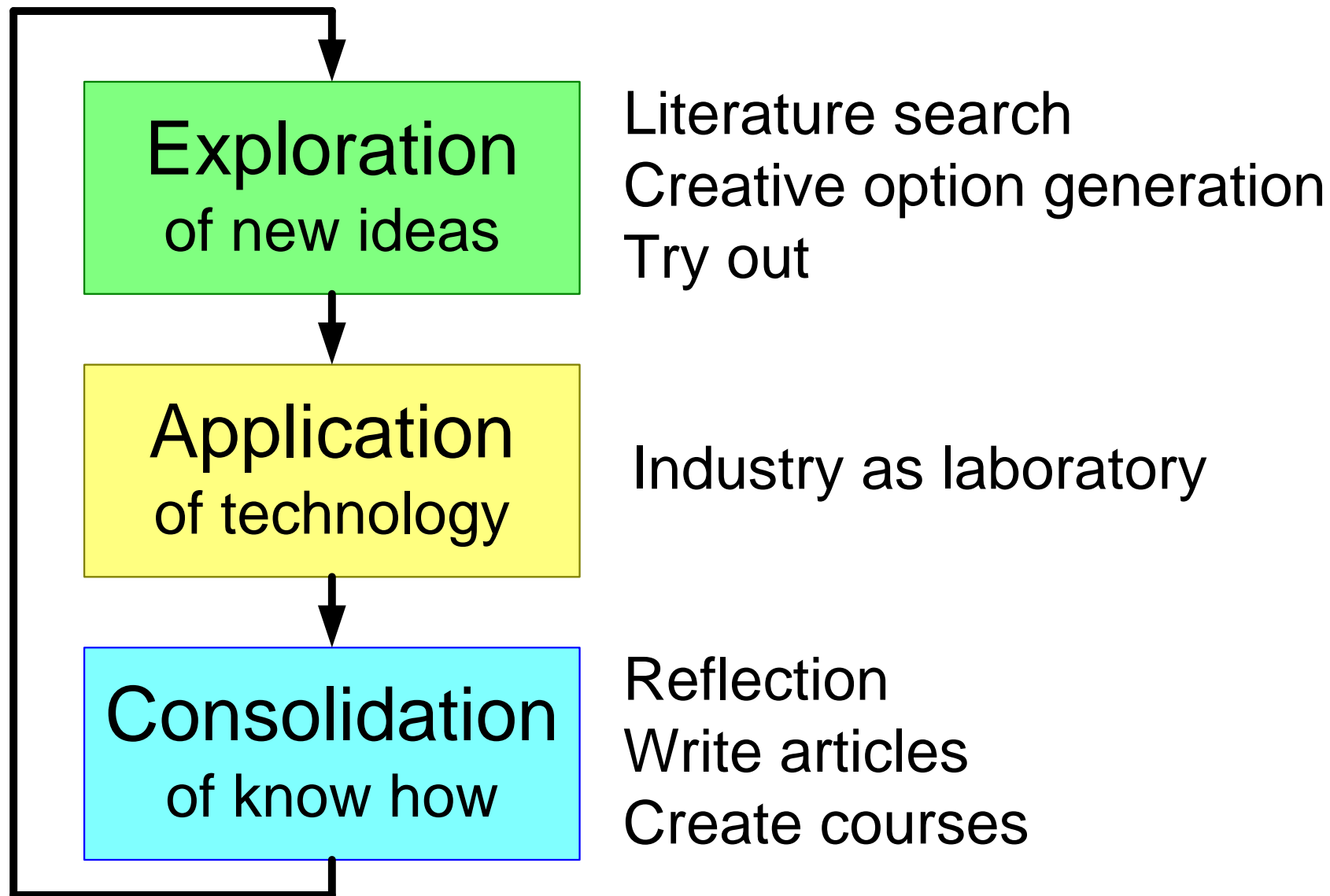
# Context of Architecting Method Research



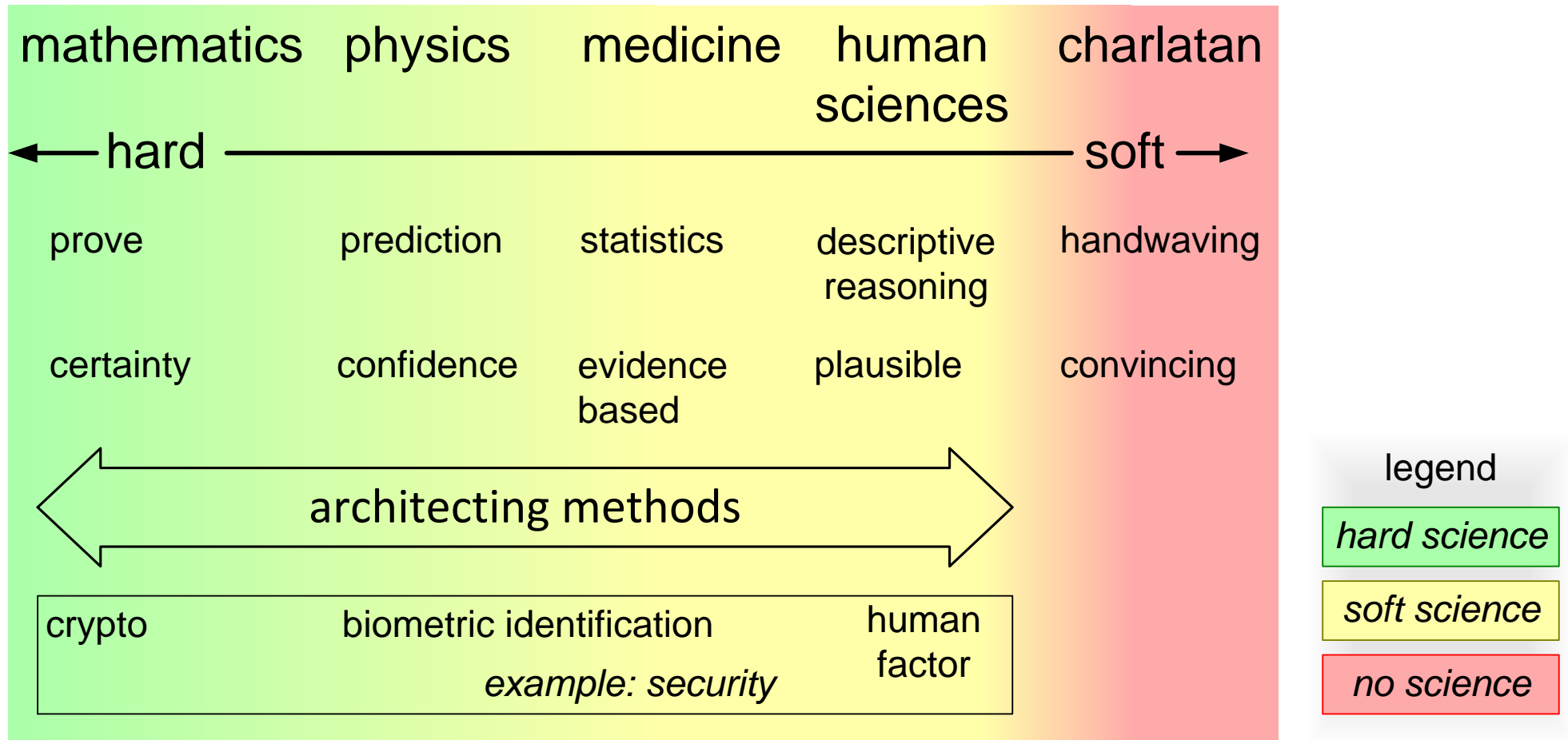


# Technology Management Cycle

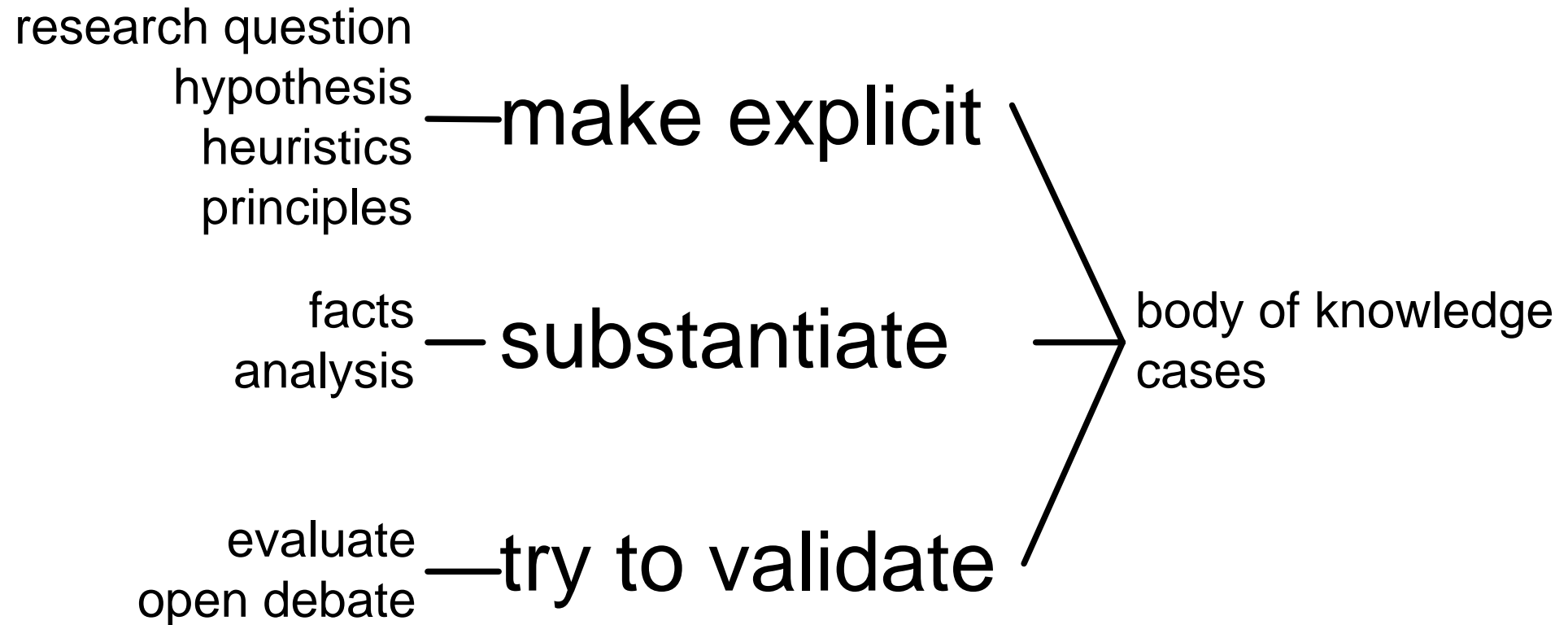
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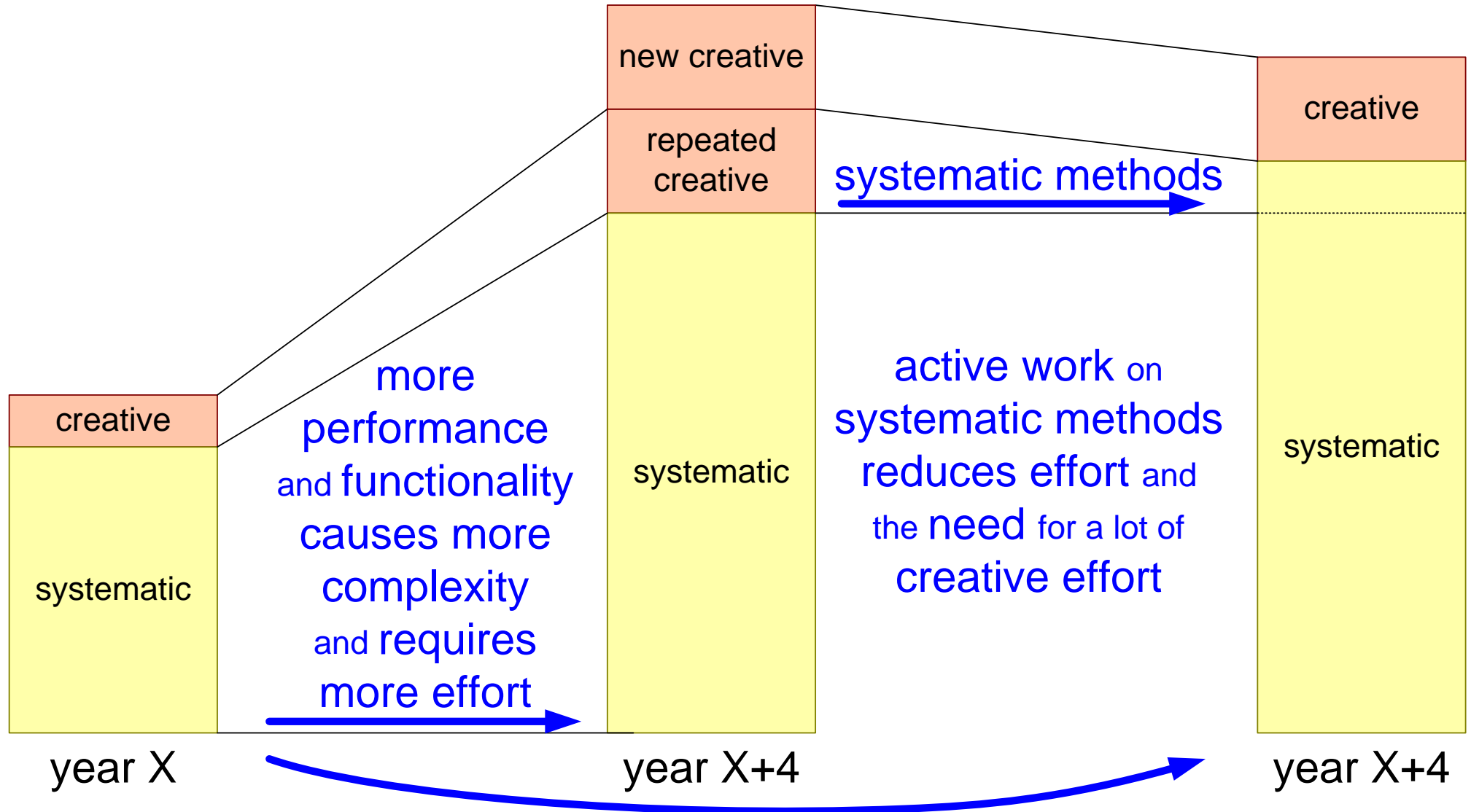
# Spectrum of sciences

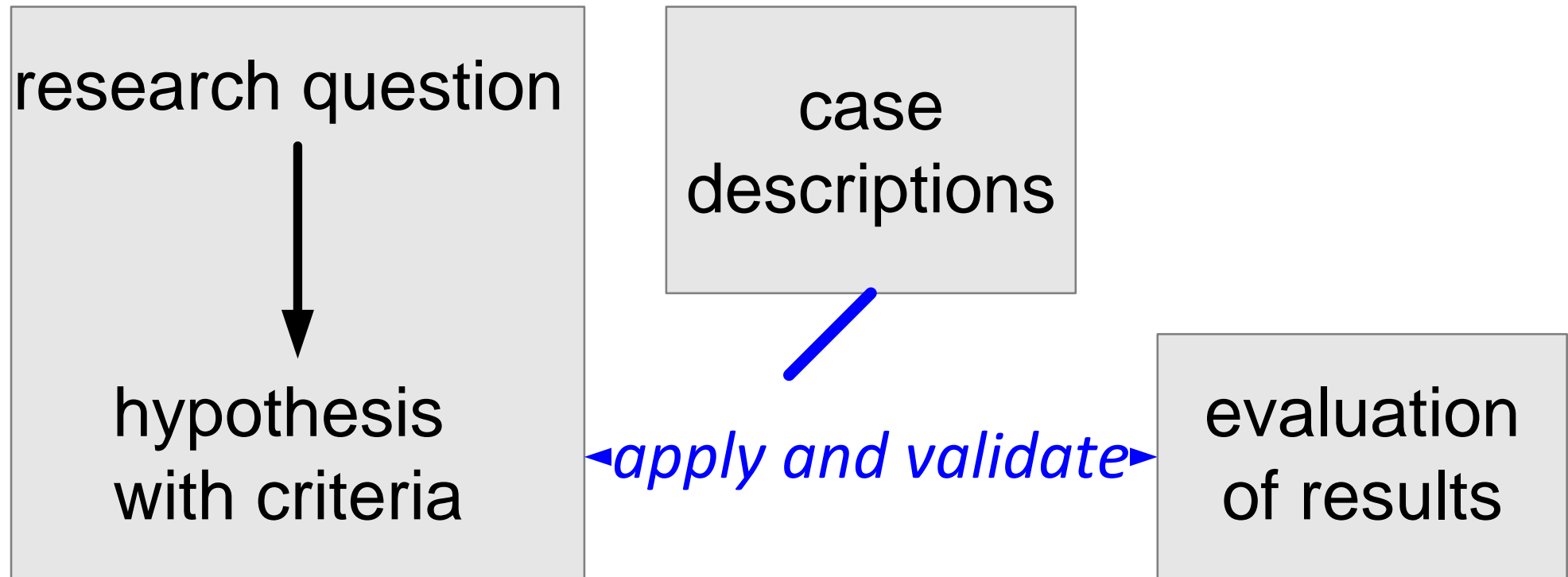


## *soft is not in conflict with scientific attitude*

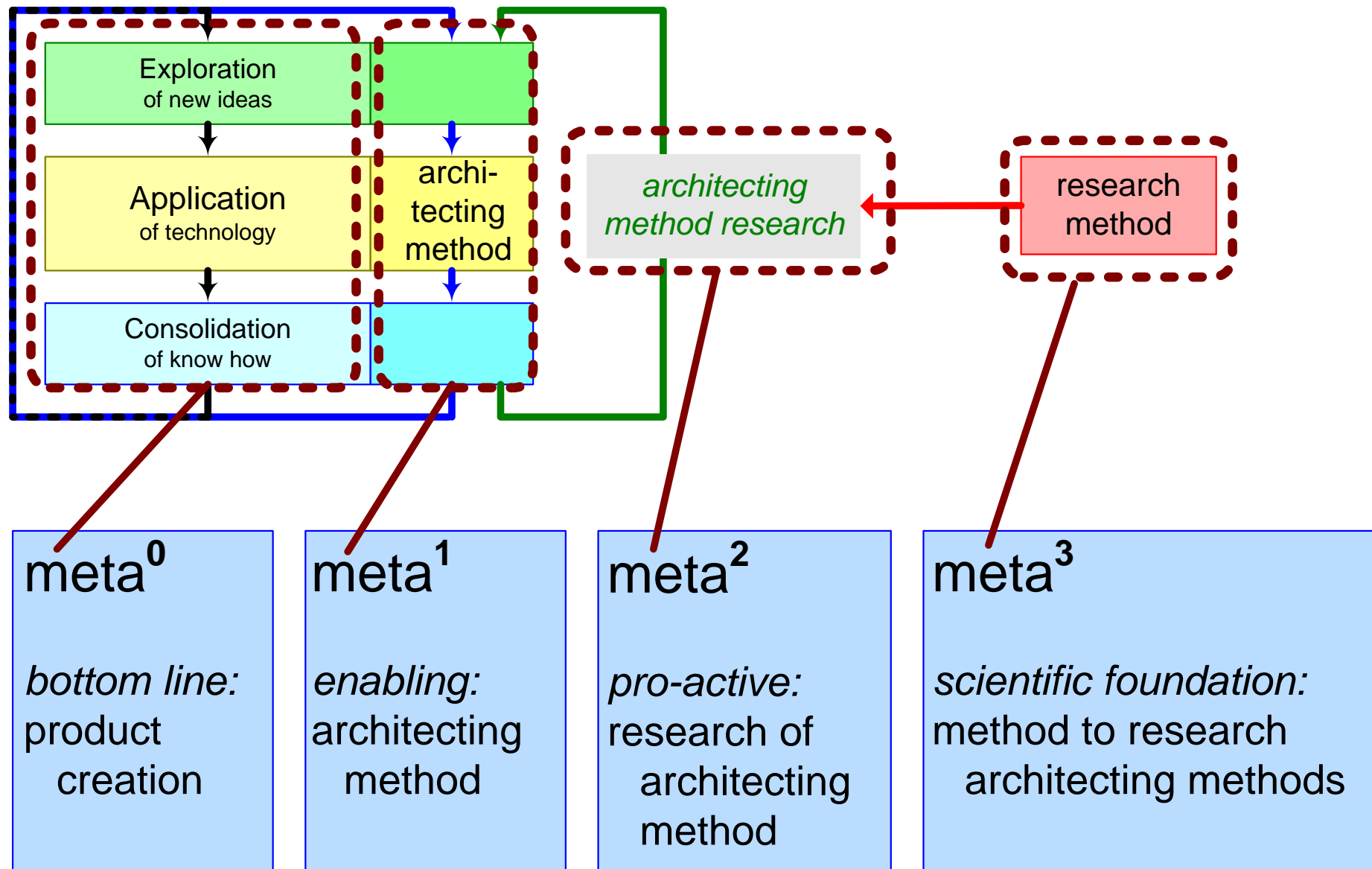


# Systematic Know-how to cope with Growing Complexity

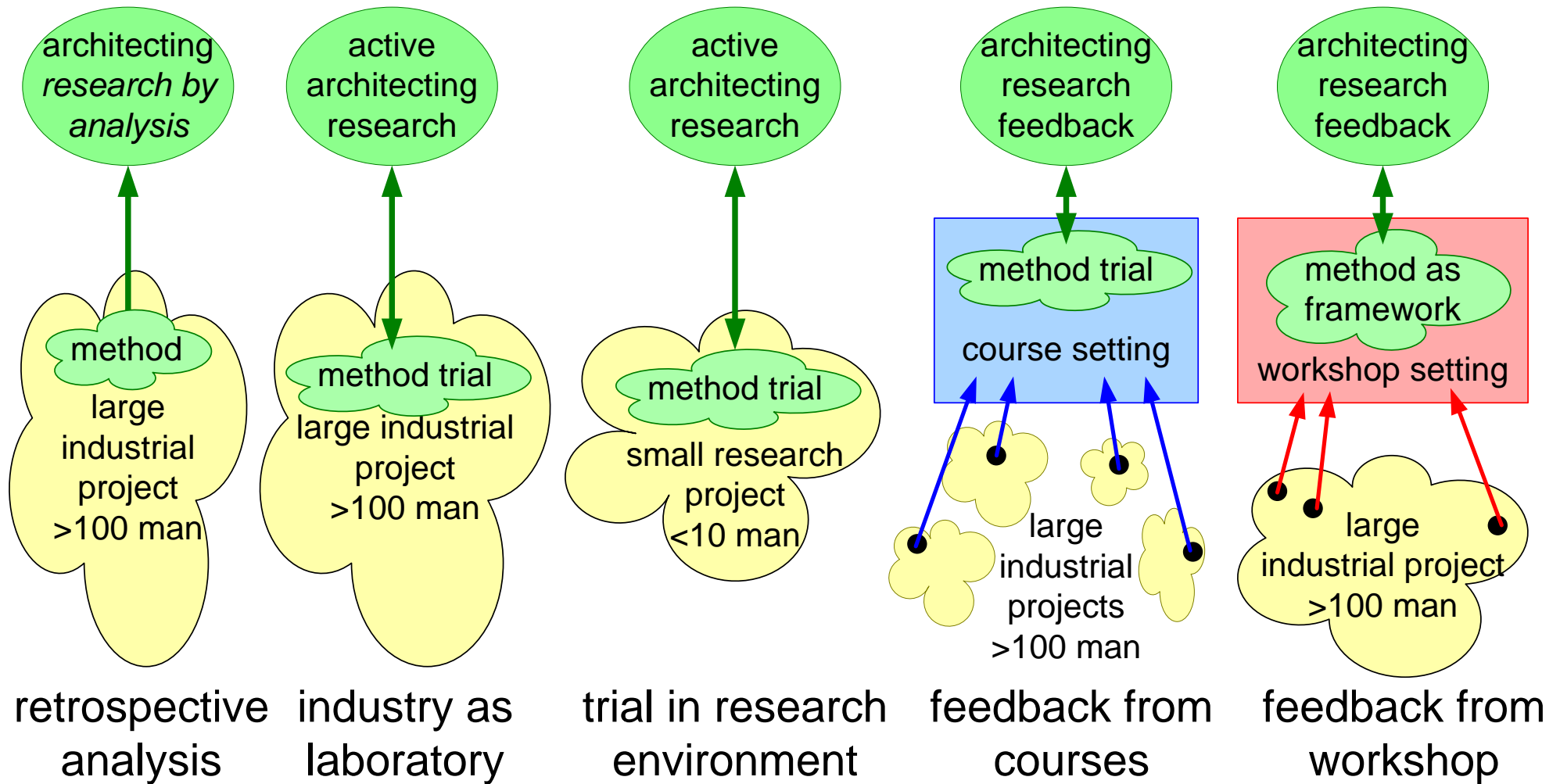




# Moving in the *meta* direction



# Other sources of case data



# Systems Engineering Research Methods

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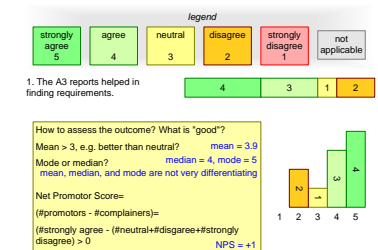
## Abstract

Research in System Engineering research inherently addresses a mix of technological issues in relation to business, process, organization, and people aspects. We show an inventory of research methods for research done in the “field”, e.g. in industry or similar organization.

### Distribution

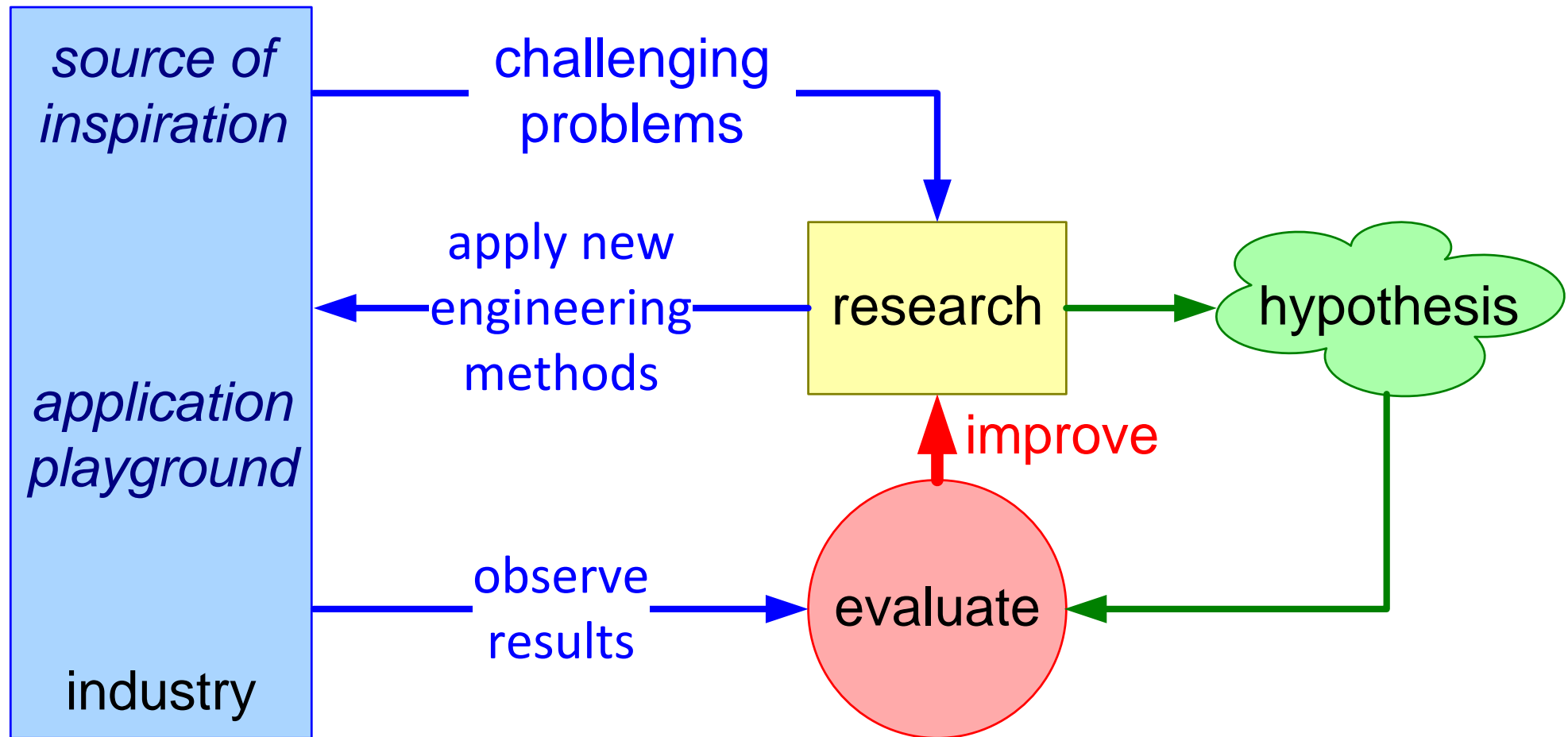
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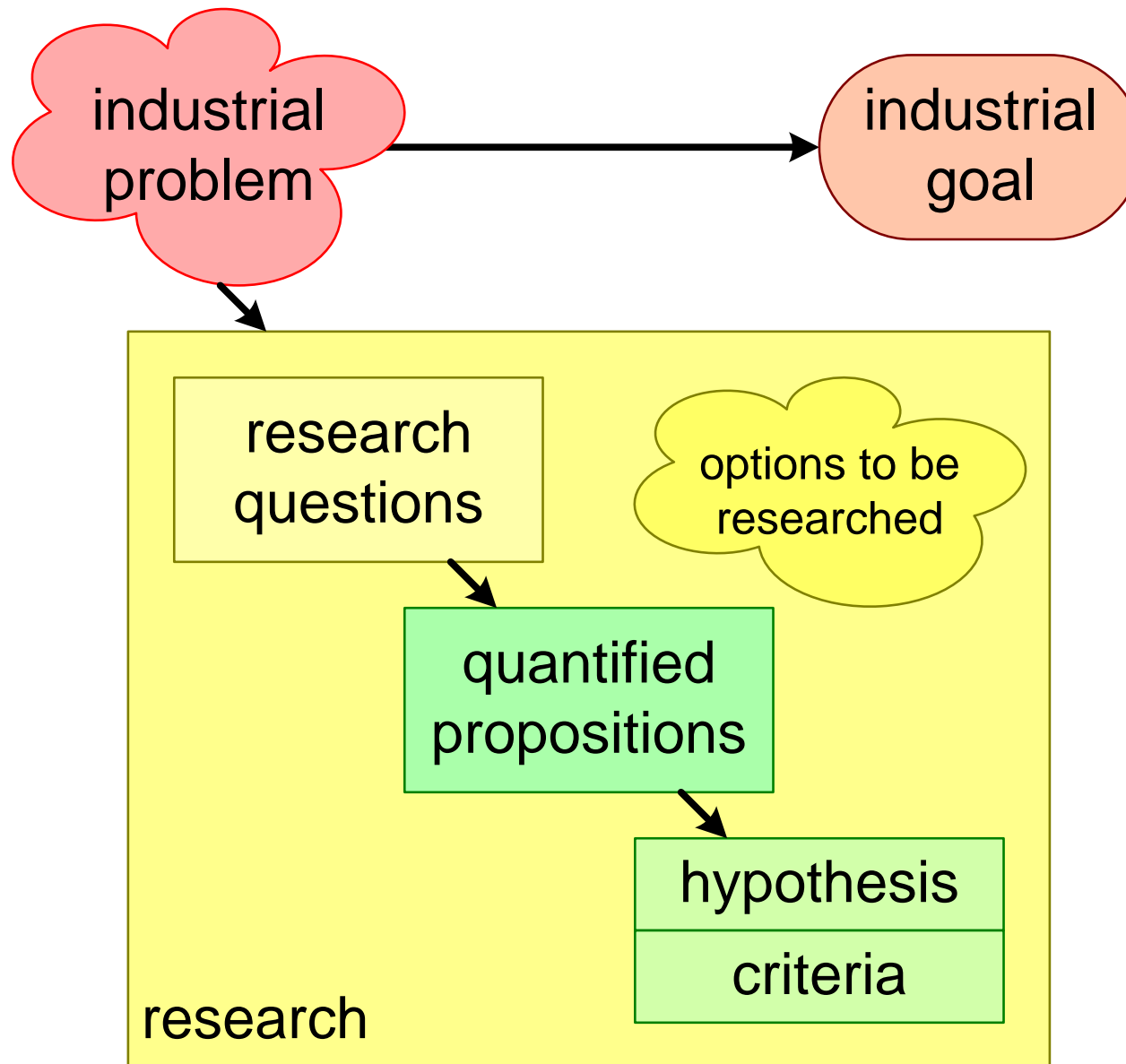
# Action Research or Industry-as-Laboratory



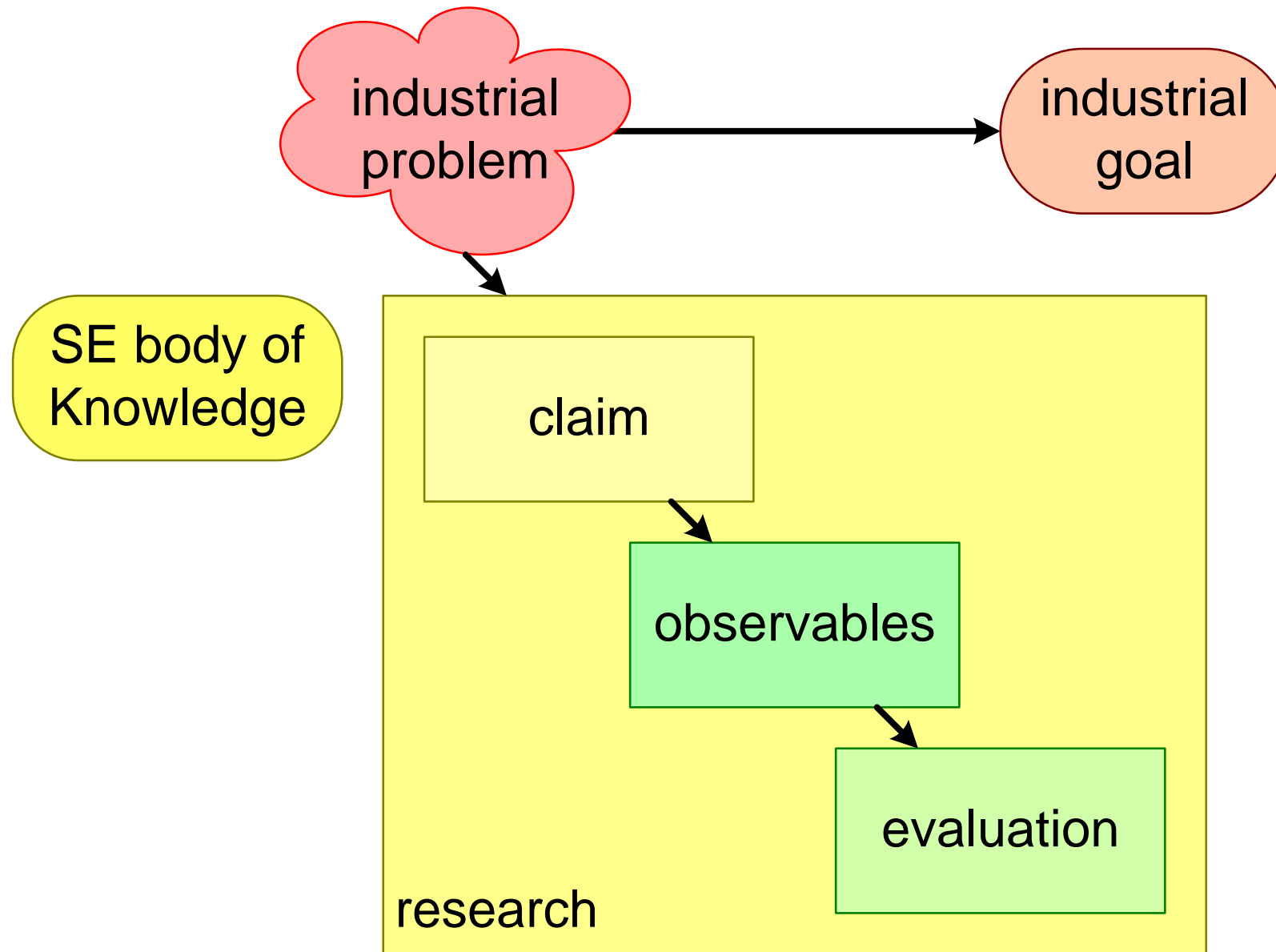
# Systems Engineer vs Researchers

	<i>systems engineer</i>	<i>researcher</i>
normal work	elicit needs, specify, design, analyze, integrate, test	observe, experiment, argue, evaluate, write
attitude	explain, educate, sell	question everything, proof opposite

# Logical Order of Research



# Simplified Order for Master Project



# Step 1: Formulate Claim

Claim: What benefits will your proposed improvements bring?

"Application of requirements traceability matrix  
will reduce changes after the definition phase significantly"

Be specific (what, who, when, how much, ...)

Does the claim address the original problem?

Is the claim realistic?

Do the benefits justify the research effort?

Do the benefits relate to the right driver?

20% or 80%  
would be better

better predictability of delivery  
earlier delivery  
better quality of delivery  
less cost or effort

## Step 2: Identify Observables

---

Observables: What observations or measurements will provide evidence for your claim?

number of changes after definition phase in past projects without method

number of changes after definition phase in current project with method

Be specific (what, who, when, how much, ...)

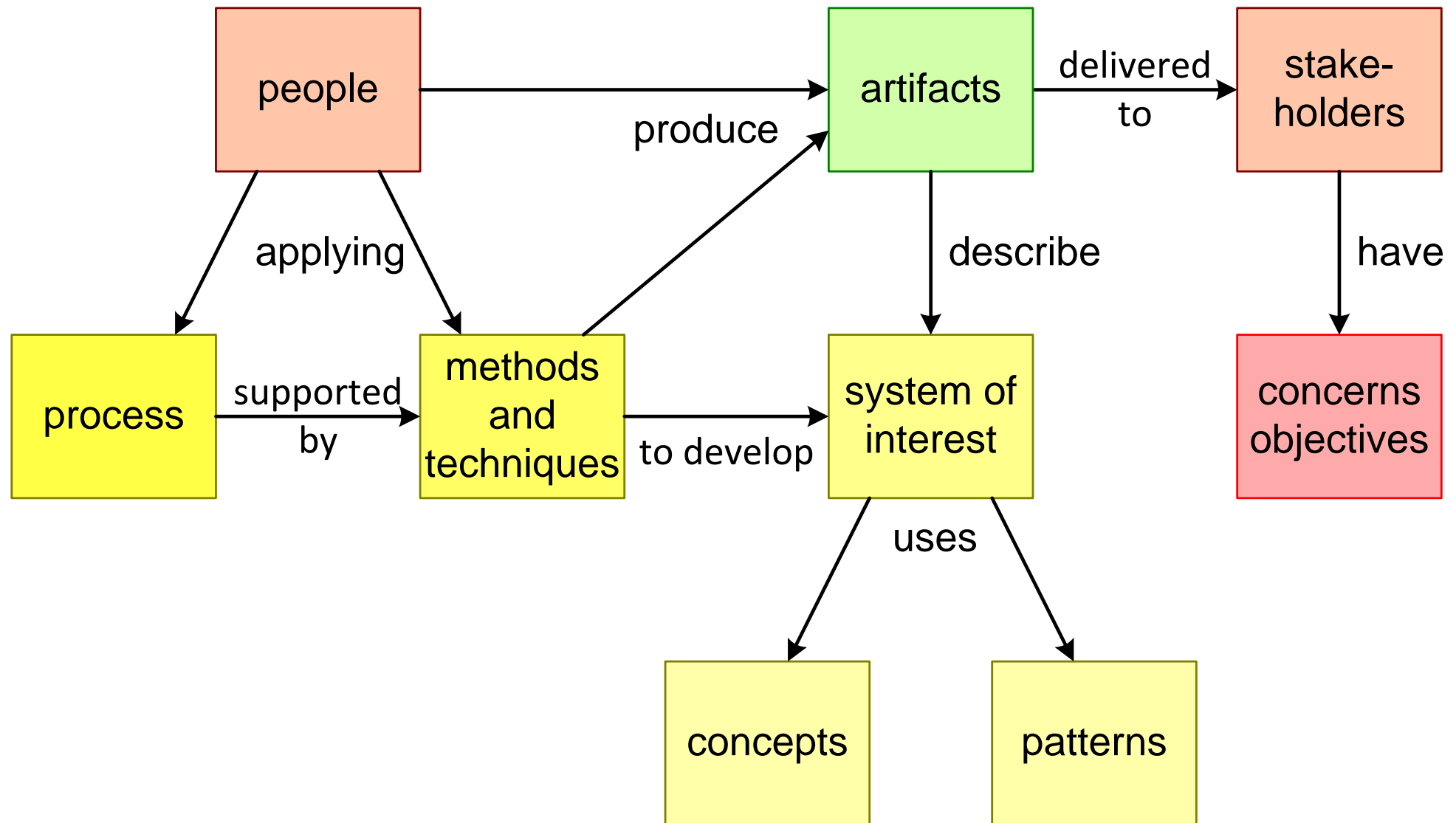
Do the observations relate to the claim?

Can the observations be made during the research period?

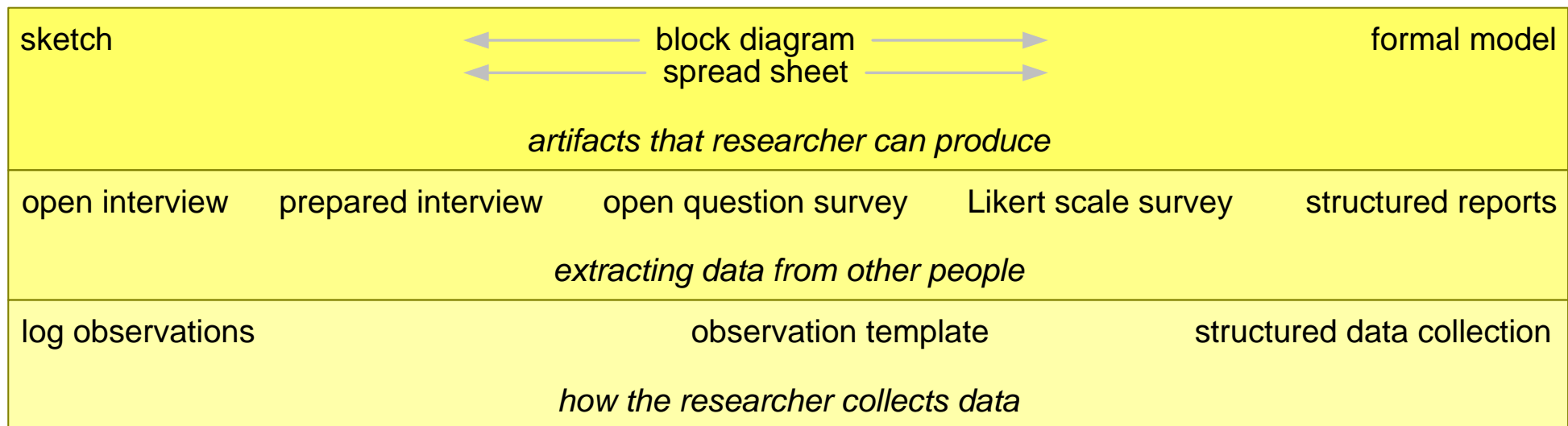
How accurate and objective are the observations?

Observe/measure the initial state before changing "zero measurement"

# What to Research; Observe Context



# Spectra of Research Methods



← free format

- . free representation
- . no formal definition
- + supports
  - discovery
  - exploration
- difficult for
  - analysis
  - comparison
  - aggregation

standardized format →

- . standardized data
- . formalized definition
- + supports
  - analysis
  - comparison
  - aggregation
- might
  - restrict inputs
  - affect observation



Word or PowerPoint file  
take notes continuously!

date/time

what

how

why

when

where

who

references, e.g. URLs; make electronic copy of any relevant material

all "raw" data, e.g. submitted questionnaires

all intermediate data, e.g. spread sheets with version numbers and dates

# Example Observation Template

Session attributes – date (year/month/day)	
<b>Kind of session:</b>	Communicate information/status
	Sell a idea/concept
	Brainstorming/generate ideas
	Decision making
	Solve/discuss problem(s)/issue(s)
	Planning
	KPI/Performance/Action log
	Team building/training
	Presentation
<b>Physical location of session:</b>	Defined meeting room
	Colleague own office
	In the factory – “on the shop floor”
<b>Planned session or not:</b>	Planned
	Unplanned
<b>A3 purpose:</b>	
<b>A3 name/link:</b>	
<b>A3 usage/iteration number:</b>	
<b>A3 usage time with stakeholders:</b>	
<b>Number of participants:</b>	
<b>Did everyone understand the A3:</b>	
<b>Did it answer some of the stakeholders questions:</b>	
<b>Create any new questions/concerns:</b>	
<b>Models changed/added:</b>	
<b>Stakeholder participation:</b>	
<b>Prefer A3 instead of A4:</b>	
<b>Observations/recordings:</b>	

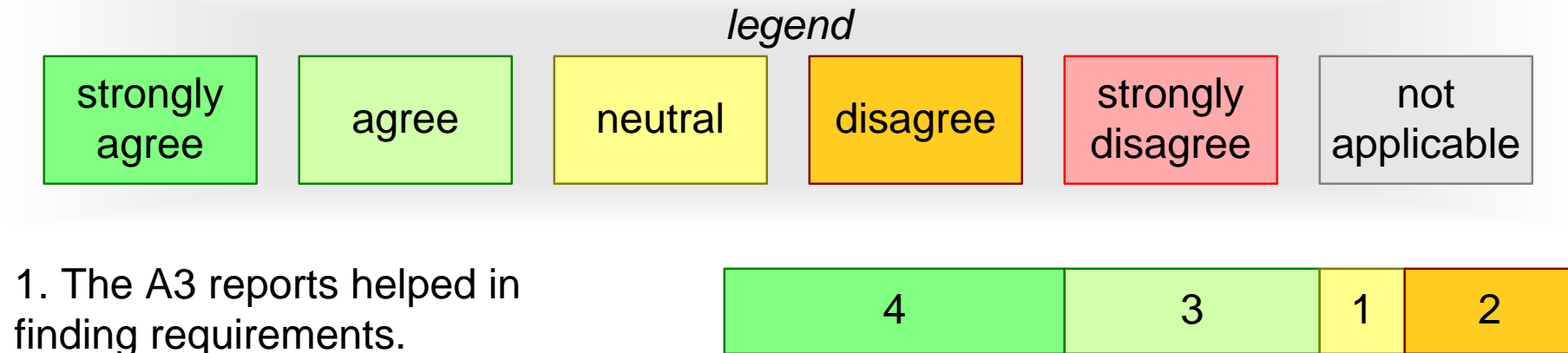
from Master Project by Espen Polanscak

# Survey with Likert Scale

## Questionnaire

	strongly agree	agree	neutral	disagree	strongly disagree	not applicable
1. The A3 reports helped in finding requirements.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

## Presentation data

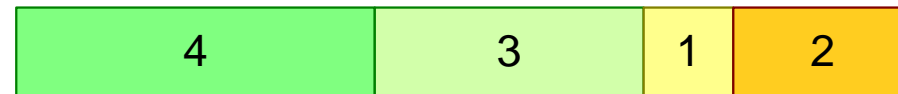


# Evaluation of Surveys

*legend*



1. The A3 reports helped in finding requirements.



How to assess the outcome? What is "good"?

Mean > 3, e.g. better than neutral?      mean = 3.9

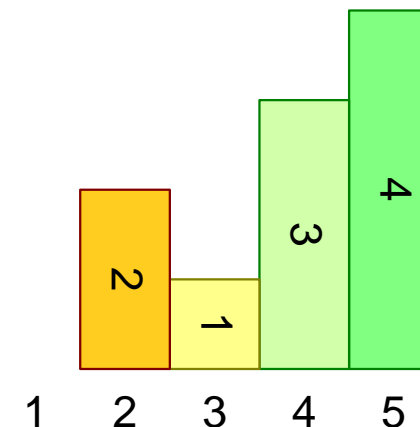
Mode or median?      median = 4, mode = 5  
mean, median, and mode are not very differentiating

Net Promotor Score=

(#promoters - #complainers)=

(#strongly agree - (#neutral+#disagree+#strongly disagree) > 0

NPS = +1



# References

## Action research:

<http://cadres.pepperdine.edu/ccar/define.html>

O'Brien, R. 1998. *An Overview of the Methodological Approach of Action Research*. University of Toronto [http://www.web.ca/robrien/papers/arfinal.html#\\_edn2](http://www.web.ca/robrien/papers/arfinal.html#_edn2)

Hilary Bradbury Huang, 2010. *What is good action research?: Why the resurgent interest?* Action Research 2010; 8; 93

## Industry-as-Laboratory:

Colin Potts. *Software-engineering research revisited*. IEEE Software, Vol. 10, No. 5:19–28, September/October 1993.

Gerrit Muller and W. P. Maurice Heemels, *Five Years of Multi-Disciplinary Academic and Industrial Research: Lessons Learned*; CSER 2007 in Hoboken NJ

## Case Study research:

Robert K. Yin, *Case Study Research Design and Methods*. Sage Publications Inc, 5<sup>th</sup> edition, May 2013

## Likert Scale:

Jamieson, Susan. (2004). *Likert scales: how to (ab)use them*. Medical Education. <http://xa.yimg.com/kq/groups/18751725/128169439/name/1LikertScales.pdf>

## Net Promotor Score:

Frederich Reichheld *The One Number You Need to Grow*, Harvard Business Review 2003, <http://hbr.org/2003/12/the-one-number-you-need-to-grow/ar/1>

Keiningham, T, L. Aksoy, L. Cooil, B. Andreassen, T, W. (2008). *Net Promoter, Recommendations, and Business Performance: A Clarification on Morgan and Rego*. Marketing Science. Vol.27, No. 3, May-June 2008, pp. 531-532. <http://www2.owen.vanderbilt.edu/bruce.cooil/Documents/Publications/2008--Marketing%20Science.pdf>

**Tools and support** see: <https://min.usn.no/student/tjenester-for-student/it-tjenester/>

# How to Research Methodologies

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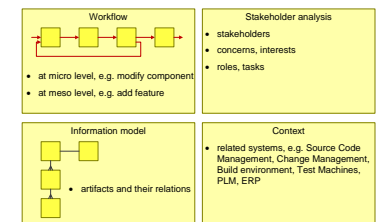
## Abstract

This presentation explains how methodology research needs a context analysis.

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# Research Approach

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Determine as-is situation

in context

Determine characteristics and weaknesses

end-to-end

Determine objectives

end-to-end

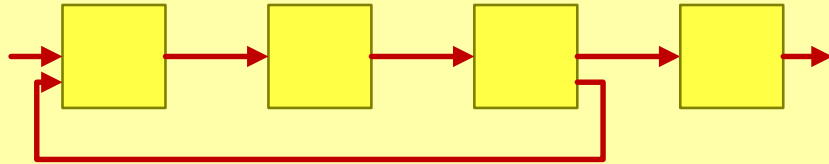
Determine to-be situation

in context

Build and validate

end-to-end  
in context

## Workflow

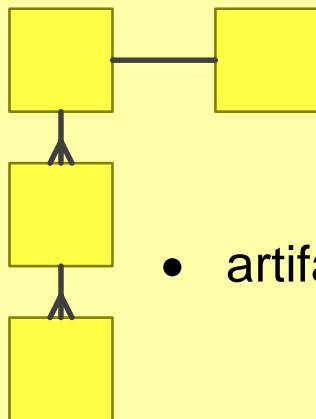


- at micro level, e.g. modify component
- at meso level, e.g. add feature

## Stakeholder analysis

- stakeholders
- concerns, interests
- roles, tasks

## Information model



- artifacts and their relations

## Context

- related systems, e.g. Source Code Management, Change Management, Build environment, Test Machines, PLM, ERP



# What should the Methodology bring?

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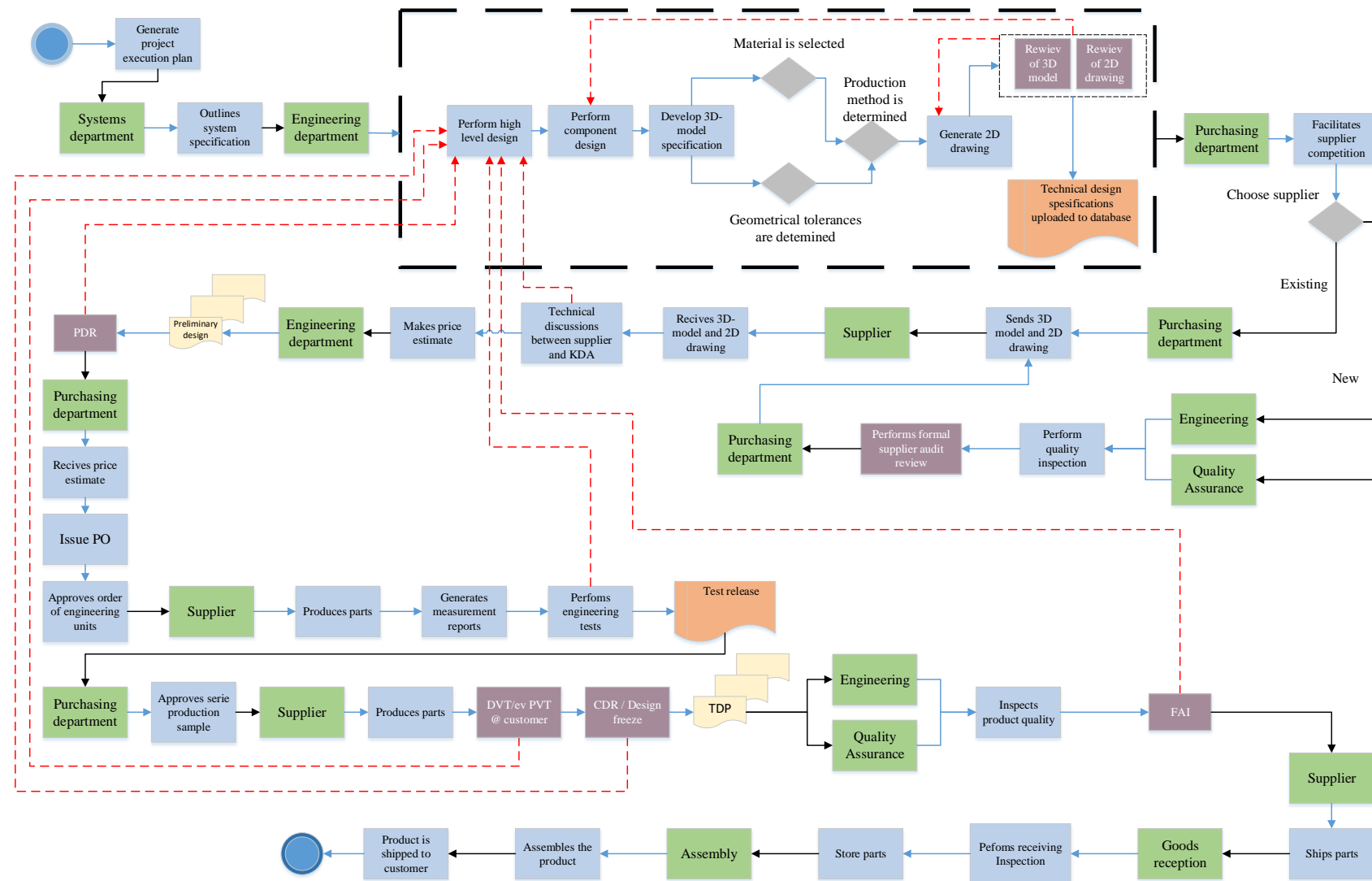
## Methodology objectives

- Time to result
- Effort
- Quality of the result
- Constraints on resources, e .g. competence
- Compatibility with existing methods, processes, tools, ...
- ...

Make the following steps for the as-is situation as far as time allows

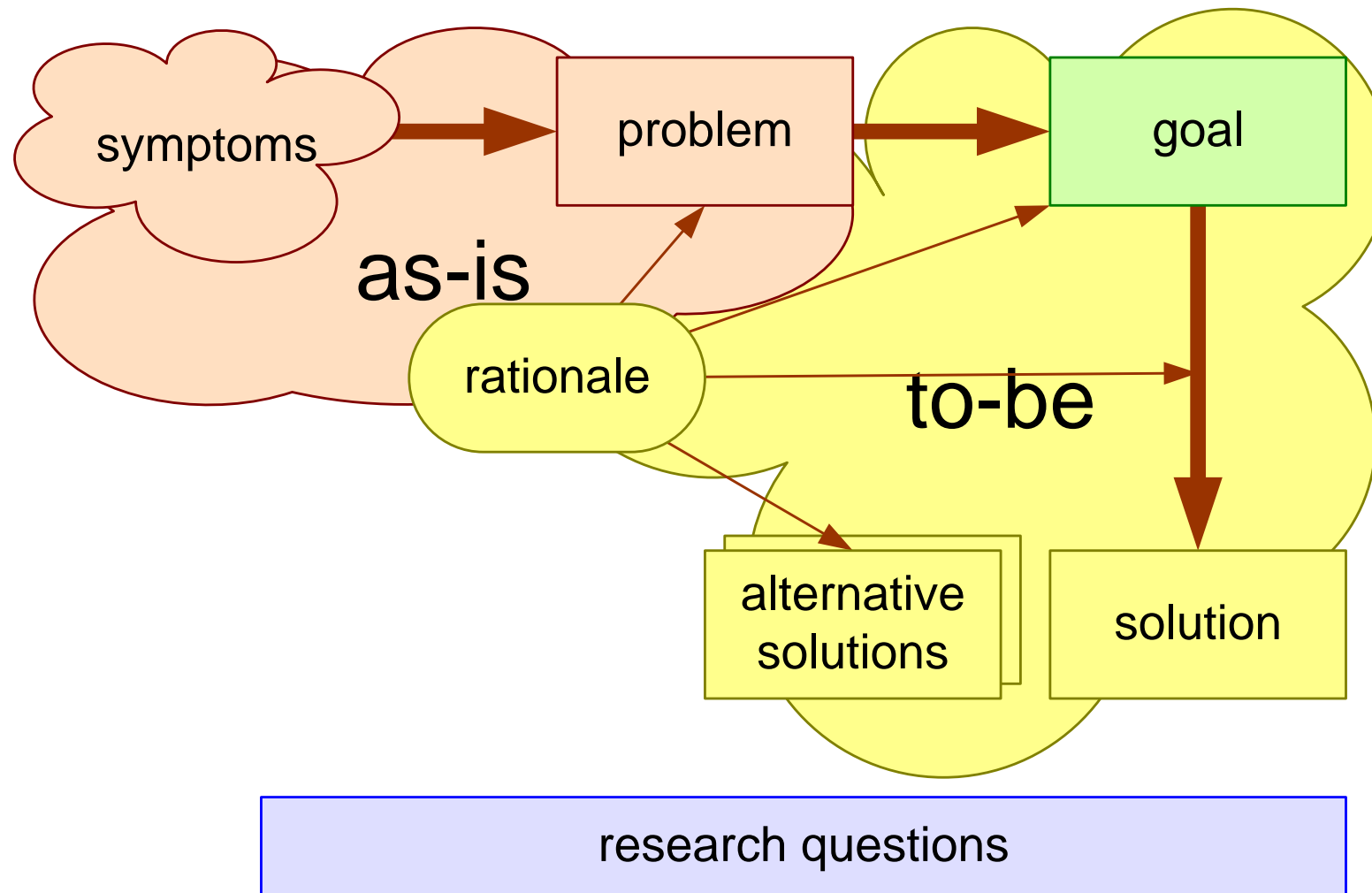
- Sketch the workflow at micro level in 10..20 steps
- Sketch the workflow at meso level in 10..20 steps
- List stakeholders
- List the 3..5 concerns for each stakeholder
- Indicate what stakeholder performs what step of the workflow
- List the incoming and outgoing artifacts for each step of the workflow
- Make an information model of the artifacts
- Identify the main characteristics per step, e.g. effort, time, quality, ...
- Quantify these characteristics

# Example Workflow Model Based Engineering



Sandberg, M., Kokkula, S., and Muller, G., Transitioning from technical 2D drawings to 3D models: a case study at defense systems, INCOSE 2019 in Orlando, FL, USA, [https://gaudisite.nl/INCOSE2019\\_SandbergEtAl\\_MBE.pdf](https://gaudisite.nl/INCOSE2019_SandbergEtAl_MBE.pdf)

# Line of Reasoning As-Is, To-Be



# Next Steps in the Context

---

Make the following steps for the as-is situation

- Sketch the workflow at macro level in 10..20 steps
- Identify ~5 Key Performance Indicators (KPIs)
- Measure current KPIs

Start shaping the to-be situation

- Explore solutions
- Repeat context assignment for to-be
- Repeat macro level steps (workflow and KPIs)

# Systems Engineering Research; Examples of Flow and Methodology

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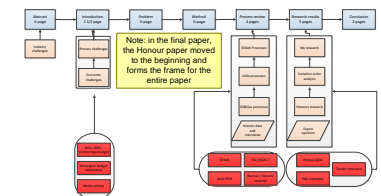
## Abstract

Research in System Engineering requires a mixture of research methods. It is a challenge to capture the various aspects in a logical flow. The research methodology is also a significant challenge. This presentation shows examples of past research of visualizing the paper flow and the research methodology.

### Distribution

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version: 0.3



**Eldar Tranøy** won the **Best Student Paper Award** at INCOSE 2014 in Las Vegas with the paper

“Reduction of Late Design Changes Through Early Phase Need Analysis”

available at [http://gaudisite.nl/INCOSE2014\\_Tran%C3%B8y\\_Muller\\_ReductionOfLateDesignChanges.pdf](http://gaudisite.nl/INCOSE2014_Tran%C3%B8y_Muller_ReductionOfLateDesignChanges.pdf)

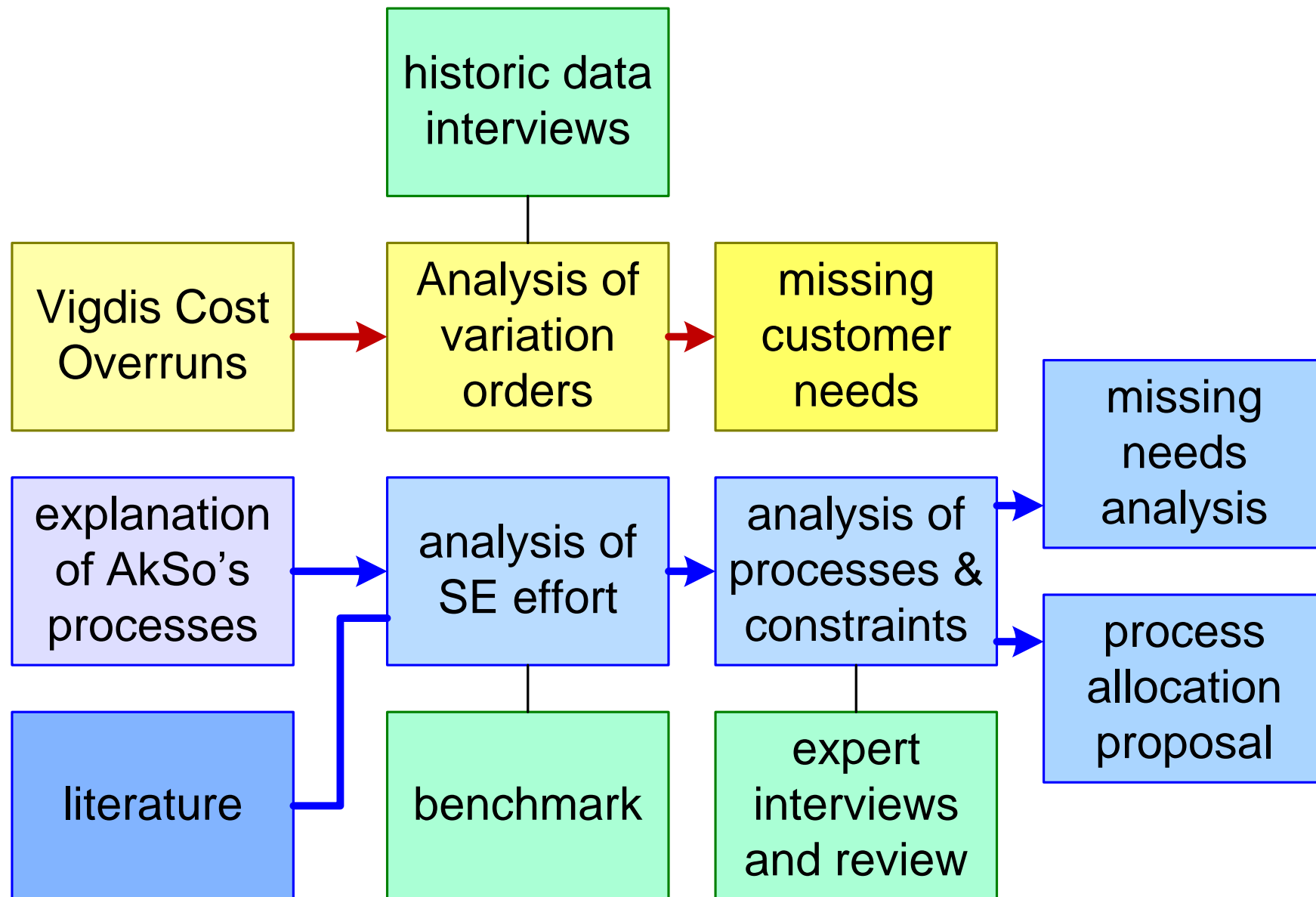
The following slides show some of the attempts of finding the flow for this paper by Eldar Tranøy and the academic supervisor.

# Meta Levels and Scopes by Supervisor

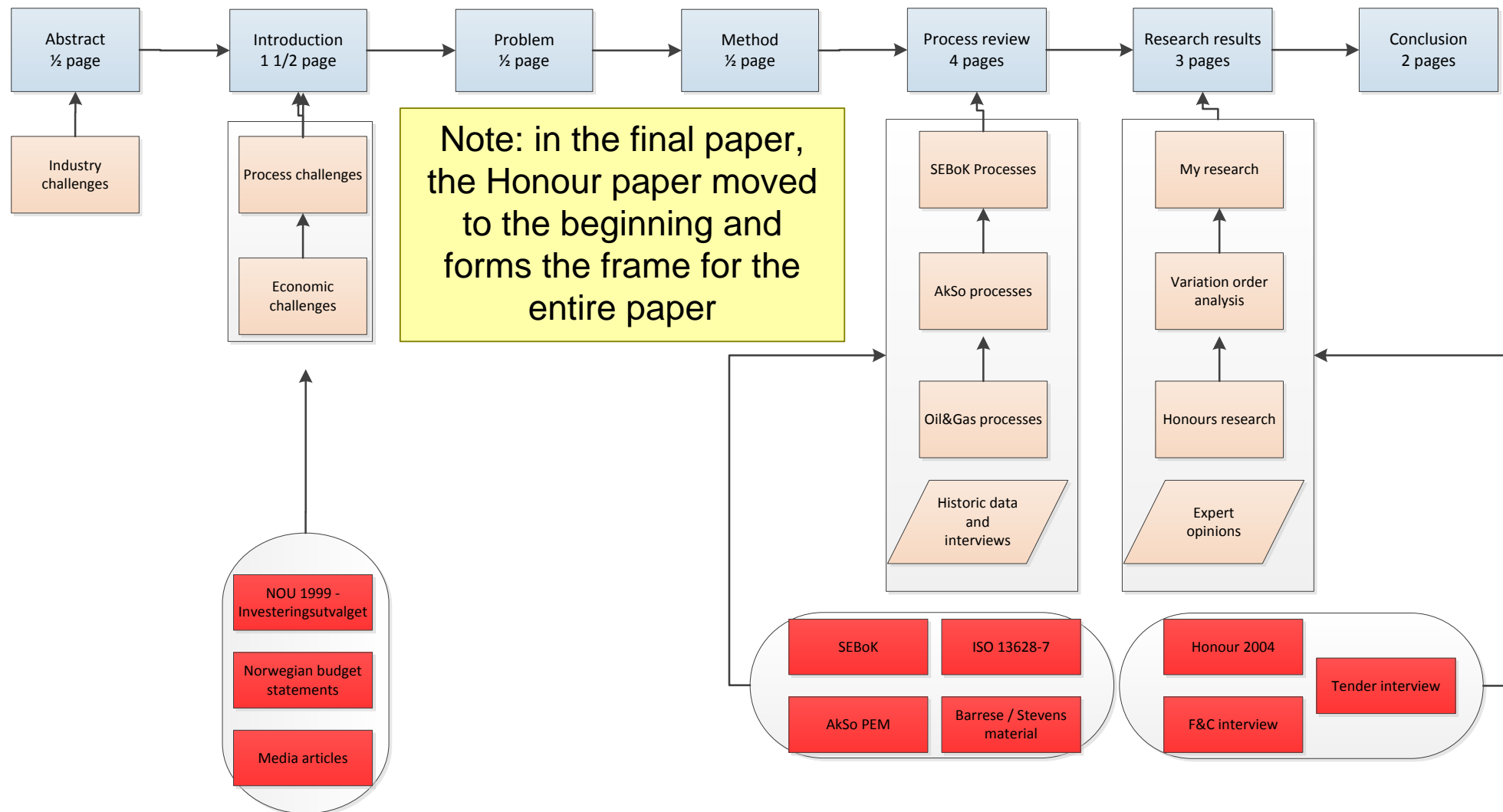
	Meta <sup>0</sup> system-of-interest	Meta <sup>1</sup> SE methods	Meta <sup>2</sup> research methodology
↑ scope	Systems Engineering Body of Knowledge	SE BoK generic SE processes	Eric Honour's research
	SubSea Oil&gas domain	SubSea Oil&gas SE processes	
	SubSea Equipment Supplier	Vigdis subsea installation	AkSo's SE process
			Eldar's research
	Meta (abstraction) level →		



# Paper Flow Proposed by Supervisor



# The Book Plan that Eldar Made at the Start



**Linda Lønmo** wrote the paper

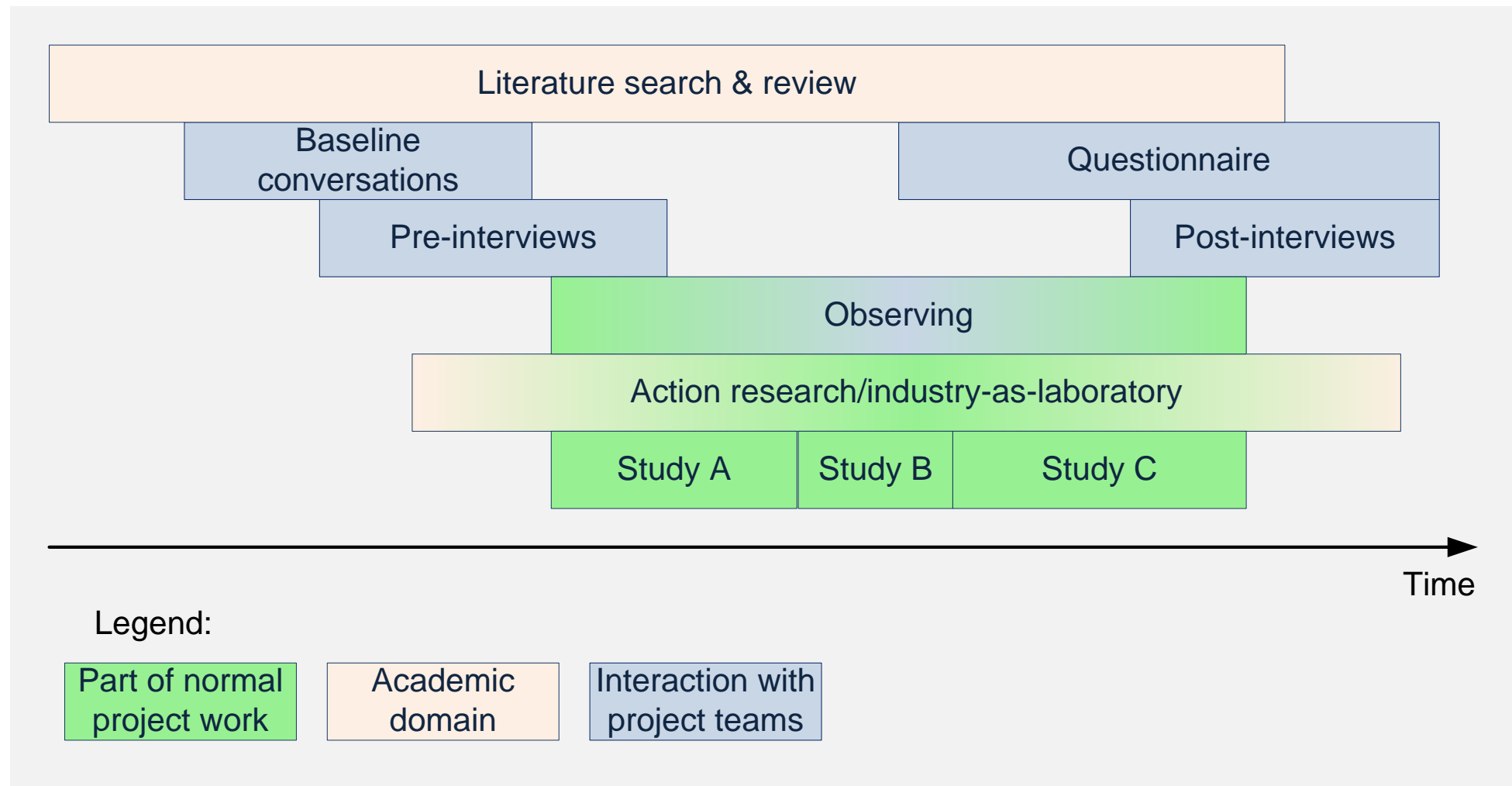
“Concept Selection - Applying Pugh Matrices in the  
Subsea Processing Domain”

for INCOSE 2014 in Las Vegas

available at [http://gaudisite.nl/  
INCOSE2014\\_Lonmo\\_Muller\\_ConceptSelection.pdf](http://gaudisite.nl/INCOSE2014_Lonmo_Muller_ConceptSelection.pdf)

The following slide shows the visualization of the research methodology by Linda Lønmo.

# Example Research Methodology by Linda



from: "Concept Selection - Applying Pugh Matrices in the Subsea Processing Domain" by Linda Lønmo  
INCOSE 2014 in Las Vegas [http://gaudisite.nl/INCOSE2014\\_Lonmo\\_Muller\\_ConceptSelection.pdf](http://gaudisite.nl/INCOSE2014_Lonmo_Muller_ConceptSelection.pdf)

**Anders Viken** wrote the paper

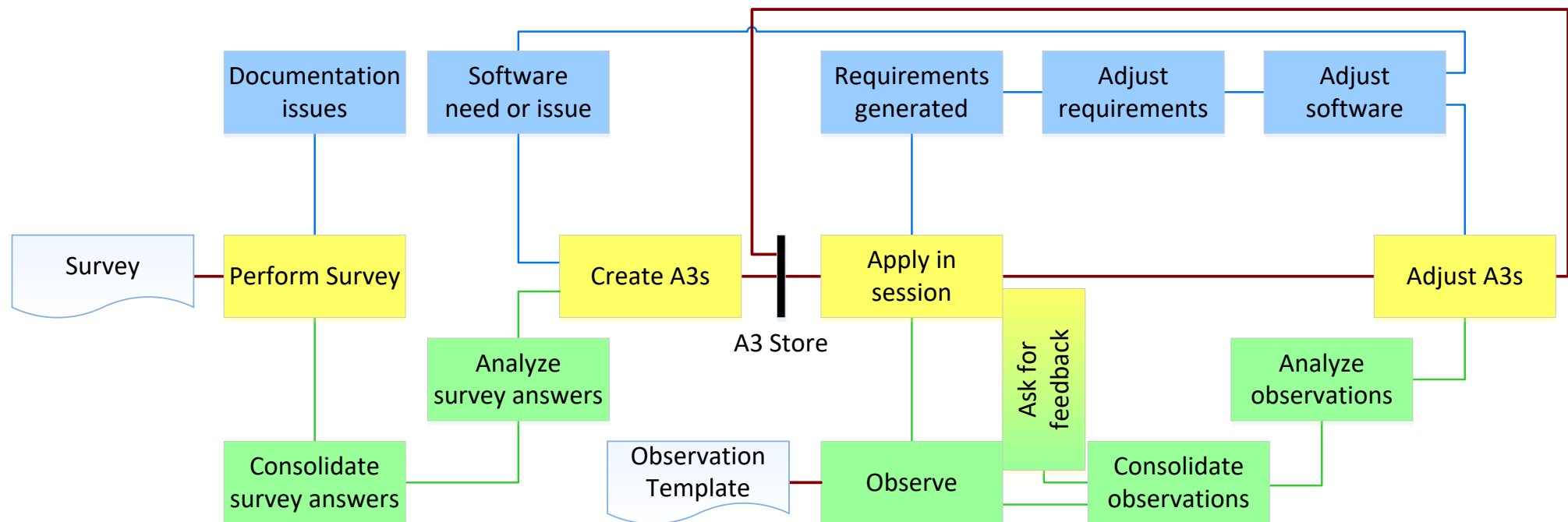
“Creating and Applying A3 Architecture Overviews: A Case Study in Software Development”

for INCOSE 2018 in Washington, DC, USA

available at [http://gaudisite.nl/INCOSE2018\\_Viken\\_MullerA3.pdf](http://gaudisite.nl/INCOSE2018_Viken_MullerA3.pdf)

The following slide shows the visualization of the research methodology by Anders Viken.

# Example Research Method by Anders



# Example Book Plan that Else Dalby made

## Industry Evaluation of a SW Test Framework Implemented at Unit level

- Title + authors - ¼ page
- Abstract - ¼ page
- Introduction - 1 page
  - Introduction to Company
  - Problem statement -> testing is costly and time consuming
  - Introduction to method -> framework with automated testing
  - Introduction to the case -> JUnit test framework
  - Short how the original problem will be solved
  - Short how the method serves the goal
- Current situation and problems - 2 page
  - Explain deeper the reasons why the department is interested in framework + automated testing (1 page)
  - How testing of SW is done in the department today (1 page)
- Research methodology - 1 ¼ page
  - Action research
  - Industry-as-laboratory
  - How I did my research => experiment + interviews + literature
  - How reliable and objective are the results of my research?
- Literature review - 1 page
  - Automated testing framework domain – what has been done?
- Main body - 6 pages
  - JUnit testing framework (1 ¼ page)
    - How and what to test with JUnit
    - How and what to test with EasyMock extension
  - Use of a test framework in the department (3 ¾ pages)
    - How testing of SW in the department is performed in the experiment (3/4 page)
    - Observations and findings (1 ½ page)
      - Summary of data collected in the experiment and during interviews
    - Cost and effort (1 ½ page)
      - Analysis of data collected – Is the case "JUnit implementation" a success? Best practices, limitations, benefits, drawbacks. (How well is the problem solved?)
  - Use of test frameworks in industry (1 pages)
    - Results – Evaluation of the SE method based on analysis of the data collected from the case. (How well does the method fit and serve its goal?)
- Conclusions - 1 ½ pages
  - Repeat: mention that the JUnit test framework can be recommended to the department with some restrictions
  - Repeat and summary from results how well the SE method fits and serves the goal of reducing cost and time of testing
  - Repeat and summary from results about limitations, benefits and drawbacks to the method
  - Reflection (1/2 page)
    - Lessons learned
    - Mention of how the research methodology worked out
- Future research - 1/2 page
  - Research to be done next is to find the error reduction rate with use of a test framework versus manual testing
  - Long term research was limited due to time constraints ,therefore it was hard to find data about how much money we can save with automated testing and how much resources the automated test frameworks will cost us to maintain
  - Experiment with implementation of JUnit in more than one unit was limited due to effort and time constraint
- References - 1 page

legend

case  
system-of-interest

Body of Knowledge  
systems engineering method

research method

Else Dalby's Book plan of  
her master project in 2013

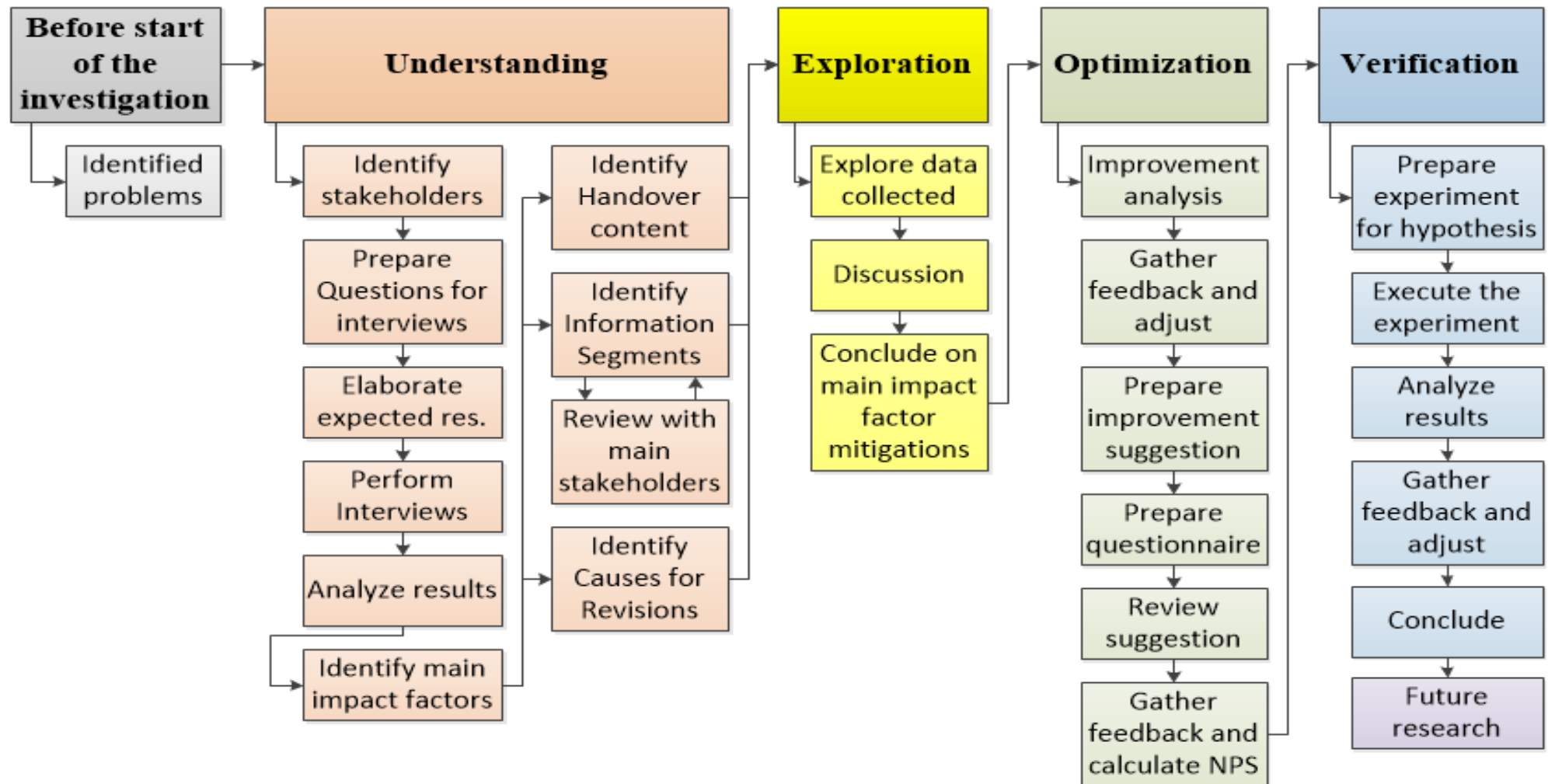
**Erik Thygesen** won the **Best Student Paper Award** at INCOSE 2019 in Orlando with the paper

“Improving the information transfer between engineering and installation; case study at AS Nymo”

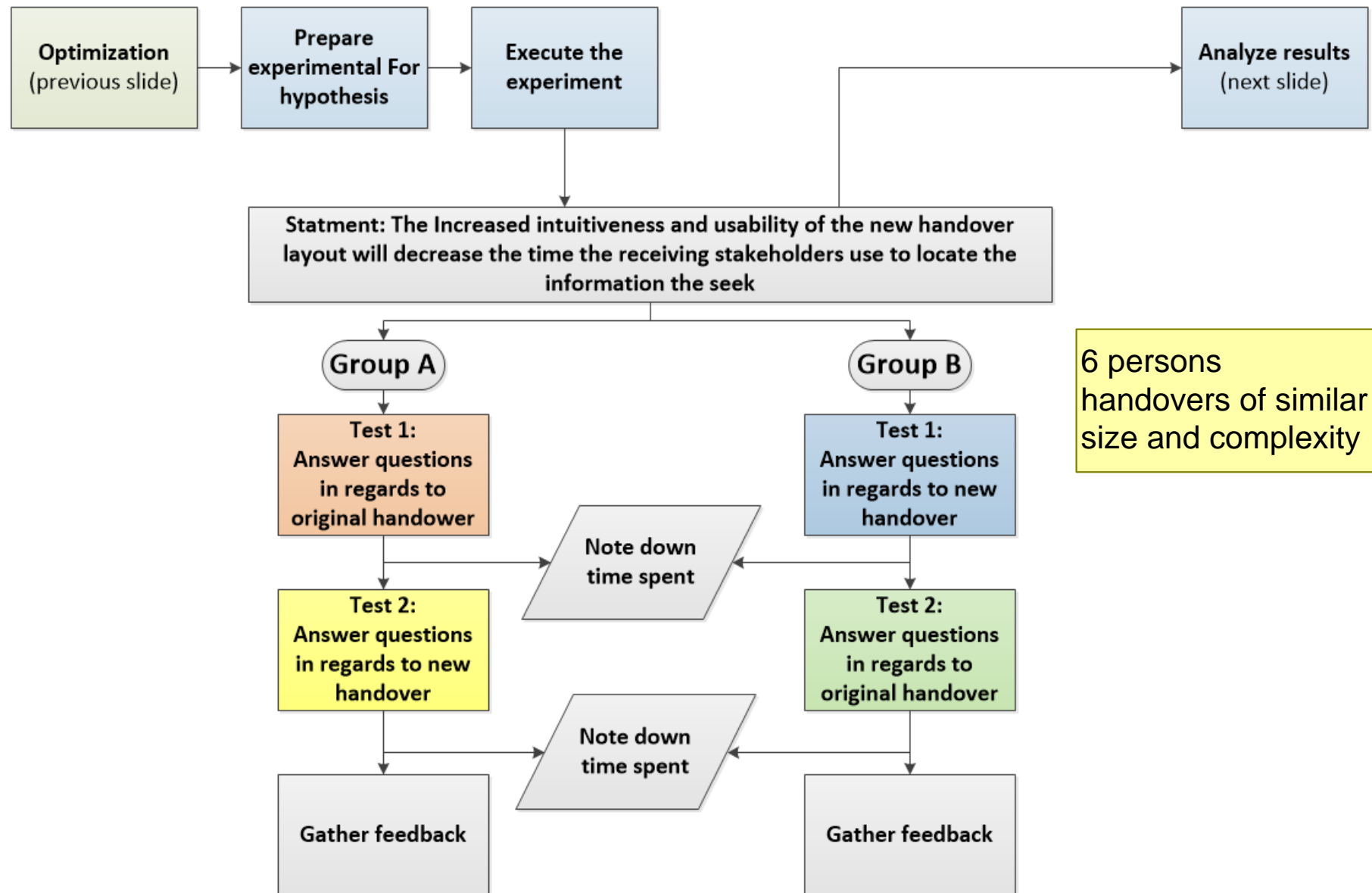
available at [https://gaudisite.nl/  
INCOSE2019\\_ThygesenEtAl\\_InformationTransferToInstallation.pdf](https://gaudisite.nl/INCOSE2019_ThygesenEtAl_InformationTransferToInstallation.pdf)



# Example Research Design Erik Thygesen



# Example Research Verification Erik Thygesen



See presentation E. Syverud [https://gaudisite.nl/SECRM\\_Syverud\\_Statistics.pdf](https://gaudisite.nl/SECRM_Syverud_Statistics.pdf)

See presentation S. Kokkula [https://gaudisite.nl/SECRM\\_Kokkula\\_ResearchEthicsUSN.pdf](https://gaudisite.nl/SECRM_Kokkula_ResearchEthicsUSN.pdf)

# Systems Engineering Course Research Methods; Language and Style of Academic Writing

by *Gerrit Muller*     University of South-Eastern Norway-NISE

e-mail: `gaudisite@gmail.com`

`www.gaudisite.nl`

## Abstract

The final product of the Master project is an academic paper. This presentation focuses on the style and language of academic papers.

### Distribution

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draft  
version: 0

logo  
TBD

# Plain English Language Recommendations (non-academic)

---

- Keep your sentences short
- Prefer active verbs
- Use 'you' and 'we' ————— Not for academic writing
- Choose words appropriate for the reader
- Don't be afraid to give instructions
- Avoid nominalisations
- Use positive language
- Use lists where appropriate

from Plain English Campaign

<http://www.plainenglish.co.uk/files/howto.pdf>

Avoid "I".

Avoid amplifications (e.g. *very high*).

Do not use humor.

Do not ventilate opinions.

Anchor every statement by fact or reference.

Explain every abbreviation or concept once at first occurrence; e.g., *Kongsberg Maritime (KM)* is ...

Avoid commercial language and selling or pushing.

Use Word to check spelling, grammar, and style with language English US.

Avoid passive voice, e.g. *A3 reports have been made* (passive) should be replaced by *The designers made A3 reports* (active). See <http://writingcenter.unc.edu/handouts/passive-voice/>

Frequently made mistakes by Norwegian students:

marked i.s.o. market

which i.s.o. that

use of *the* and *a* or *an*

plural and single mismatch between subject and verb



The use of ",", ";", and ":":

• commas:

in lists: *one, two, and three*

parenthetical expression: *the method under study, requirements engineering, is...*

• semicolon: use it when the two sentences are complete and closely related

• colon: use it when a list follows the sentence, e.g. we  
• *have three choices: red, green, or blue.*

# Visualization Guidelines

---

Texts should be readable: use sufficient font size.

Text and background should have sufficient contrast.

Shapes, such as boxes, should have the same size.

Use the layout (left-right, up-down, close-remote) to support the message of the diagram.

Design the layout such that there are few crossing lines.

Use colors, but limited.

Design the diagram such that it still works when printed in black and white.

Limit the amount of information in one diagram.

Two or three types of information can be combined in one diagram.

Annotate generic diagrams with specific examples; use font size and type to visually differentiate generic from specific.

Use 2D/3D drawings or photos limited.

Ensure that the message of the visualization is clear.

Add legend to explain shapes, colors, line types, axes, etc.

# Systems Engineering Course Research Methods; Structure of Academic Papers

by *Gerrit Muller*     University of South-Eastern Norway-NISE

e-mail: `gaudisite@gmail.com`

`www.gaudisite.nl`

## Abstract

The final product of the Master project is an academic paper. This presentation focuses on the structure and flow of academic papers.

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logo  
TBD

Take reader's perspective.

Make a book plan with structure of the paper:

- sections and subsections with size estimate, e.g.

  - abstract (50 to 150 words)

  - introduction (1 page)

    - domain, company, system, and case introduction

    - problem statement

    - method introduction and rationale

    - etc.

Do **not** include table of content, or list of abbreviations in the paper itself.

title, authors, abstract

introduction

domain, company, case, problem, goal

research questions, claims and observations, positioning

research methodology

main body

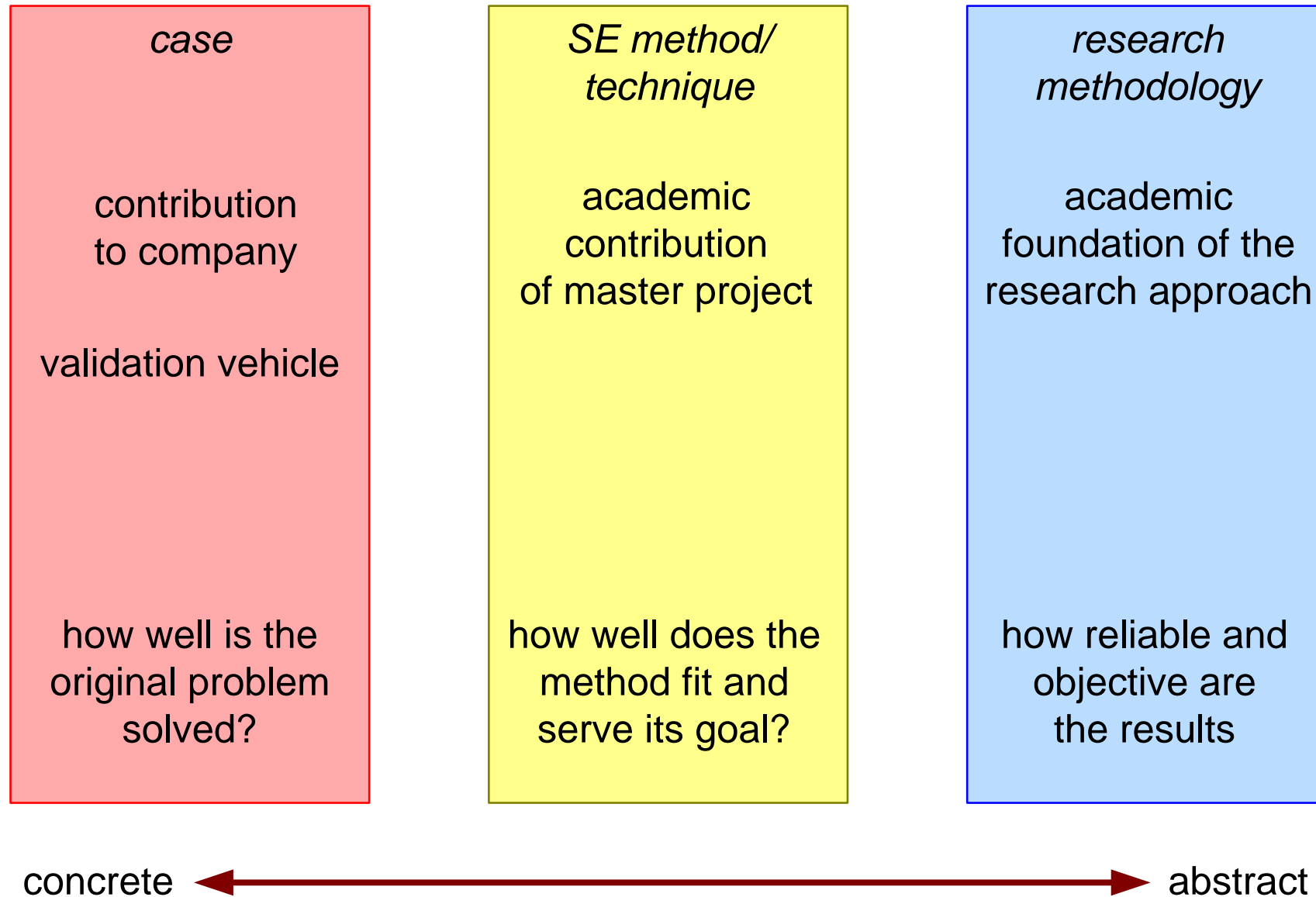
data, analysis, results

conclusions, summary

future research

references

# Multiple Threads



# Open, Elaborate, Close

---

open

elaborate

open

elaborate

close

open

elaborate

open

elaborate

close

close

close

open: introduction, question, problem, or statement

elaboration: facts, explanations, and argumentation

close: conclusion or summary

# Master Project; PERT plan

by *Gerrit Muller*      University of South-Eastern Norway

e-mail: `gaudisite@gmail.com`

`www.gaudisite.nl`

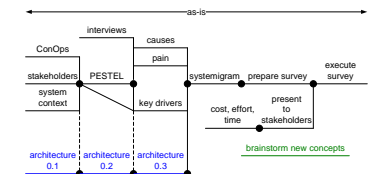
## Abstract

A PERT plan primarily shows the logic of the project plan, by showing activities and their relations. There is little or no information on resources and time. A PERT plan is more robust for changes due to project events and it provides a better overview than GANTT charts.

### Distribution

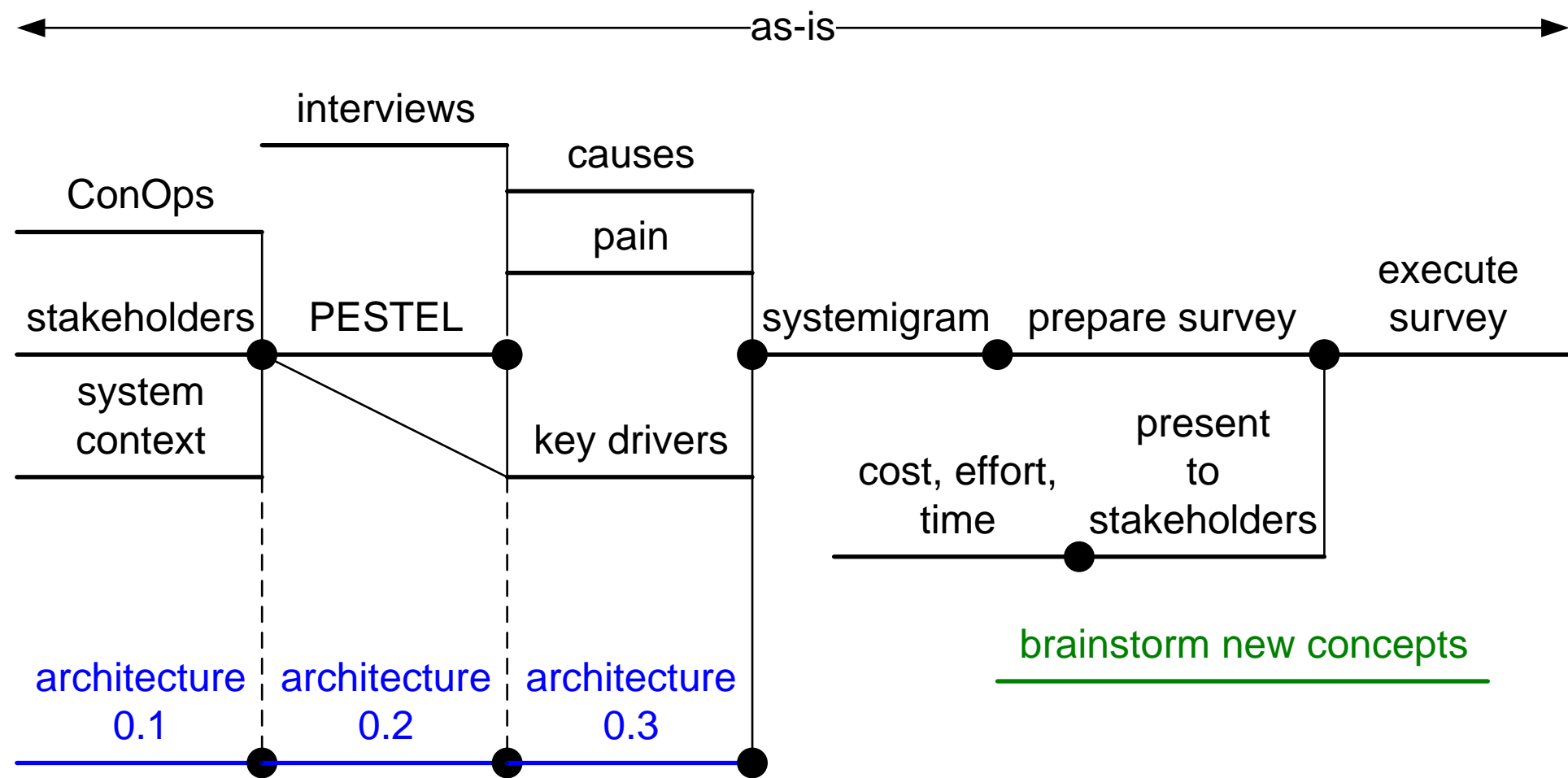
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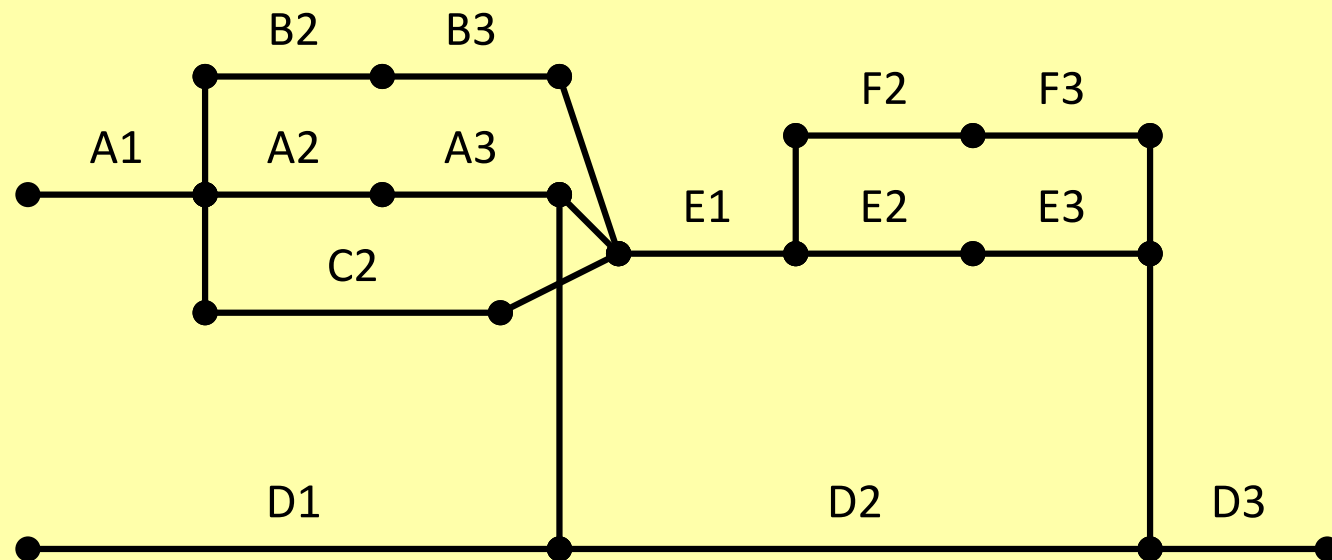


# Example PERT Plan



# Make a PERT plan for Master Project Execution

- Strive for >20 activities
- Show dependencies



- How many activities did you define so far?
- How concrete are the activities? [1 = highly generic, 5 is very specific (e.g. system, phase, stakeholder, properties, etc. defined)]

# Master Project; Writing an Abstract

by *Gerrit Muller*      University of South-Eastern Norway-NISE

e-mail: `gaudisite@gmail.com`

`www.gaudisite.nl`

## Abstract

An abstract is a brief description of the content of a paper to facilitate readers in deciding to read the paper. This presentation explains how to write an abstract. Normally, an abstract is written at the end of writing a paper. For the master project, we challenge students to write an abstract up front, to stimulate them to think through the entire project, including the expected outcome.

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*"A good abstract should answer three questions:*

*What did I do,*

*what did I learn,*

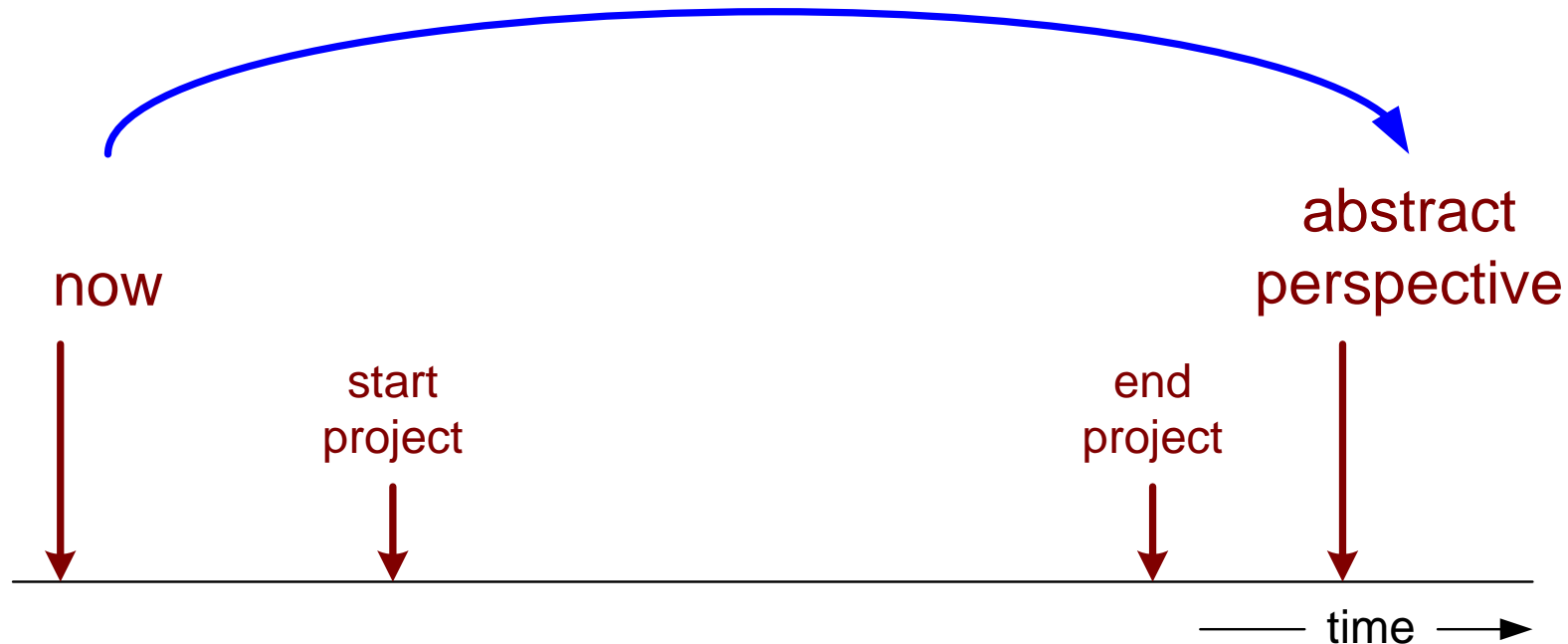
*and why is that important?*

*The key is to identify something or things that can be reused in the future."*

**Prof. Michael Pennotti, Stevens Institute of Technology**

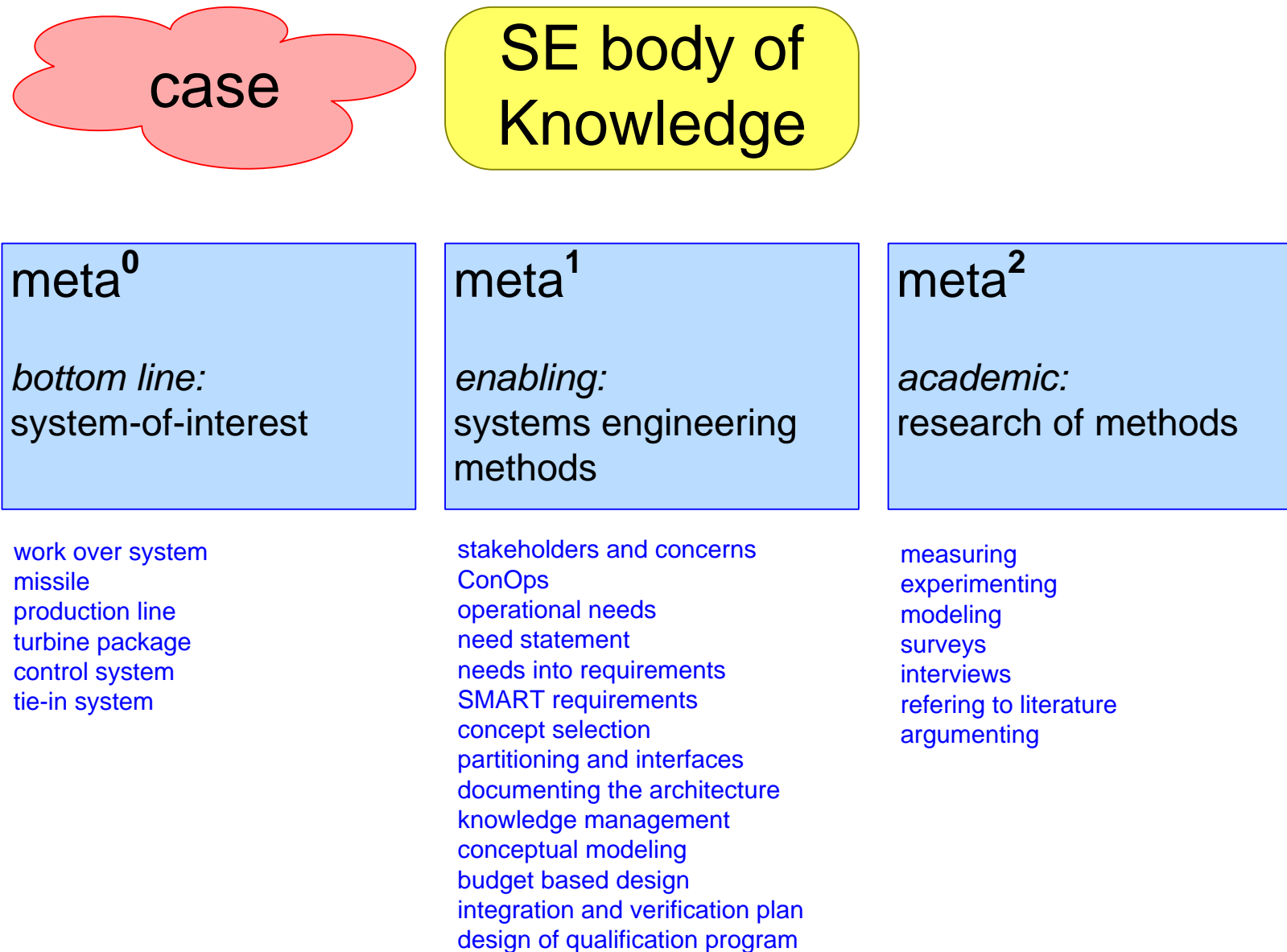
# Needed: Time Machine

"fast forward" yourself into the future  
what do you expect to be the project outcome?



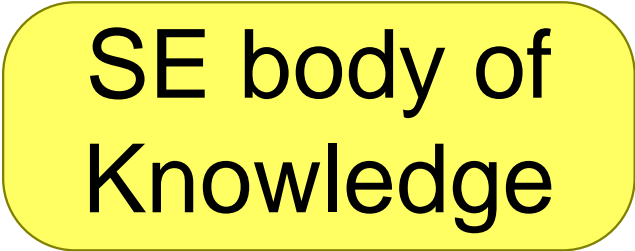
Students write an initial abstract at the start to think through what can happen. At the end of writing the paper, you write the real abstract. The academic supervisor has to accept the initial abstract before starting the project.

# Multiple Levels of Academic Abstraction





case



SE body of  
Knowledge

meta<sup>0</sup>

*bottom line:*  
system-of-interest

earning money

meta<sup>1</sup>

*enabling:*  
systems engineering  
methods

re-use  
in future projects  
in other domains

meta<sup>2</sup>

*academic:*  
research of methods

validation of  
method  
re-use

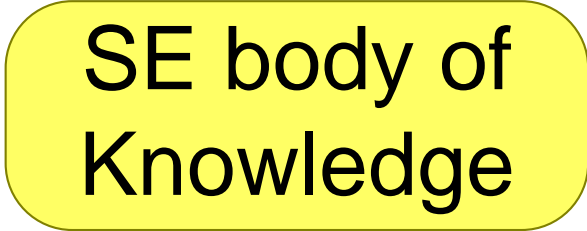


# Content of Paper

---



case



SE body of  
Knowledge

meta<sup>0</sup>

*bottom line:*  
system-of-interest

set the context  
where did you apply

domain  
system-of-interest

meta<sup>1</sup>

*enabling:*  
systems engineering  
methods

what did you apply and why

systems engineering  
challenge/need  
methods, expected benefit

meta<sup>2</sup>

*academic:*  
research of methods

what can we learn  
based on what findings

observations  
argument

Write an abstract

in 3 paragraphs

use 2 sentences per paragraph

100..150 words in total

# Master Project; Execution Phase

by *Gerrit Muller*      University of South-Eastern Norway-NISE

e-mail: `gaudisite@gmail.com`

`www.gaudisite.nl`

## Abstract

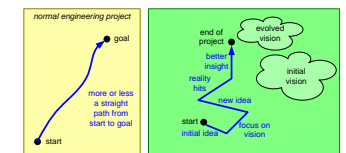
A master project in systems engineering using action research or industry as laboratory requires that the student is both researcher and engineer. In this presentation we give guidelines for the execution phase of the project to ensure that the master project student plays both roles. These roles require quite different behavior. Especially the role of researcher is new for most students.

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*Research is an adventurous journey, be perceptive and see where it goes*



*Some students in the past called it a rollercoaster....*

Discuss *way of working* and *expectations* with your *academic supervisor*.

The following slides are valid for supervision by Gerrit.

Other academic supervisors may have other doctrines.

# Recommendations for Project Execution

---

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

# You have Multiple Roles!

---

	<i>systems engineer</i>	<i>researcher</i>
normal work	elicit needs, specify, design, analyze, integrate, test	observe, experiment, argue, evaluate, write
attitude	explain, educate, sell	question everything, proof opposite

# Maintain a Detailed Research Logbook

---

Word or PowerPoint file  
take notes continuously!

date/time

what

how

why

when

where

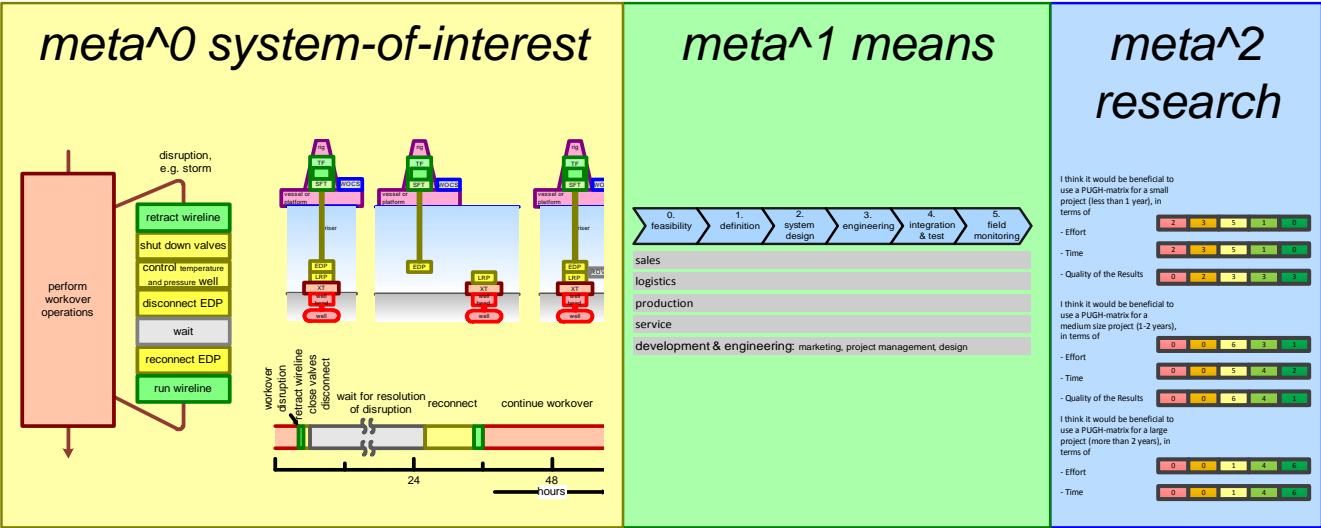
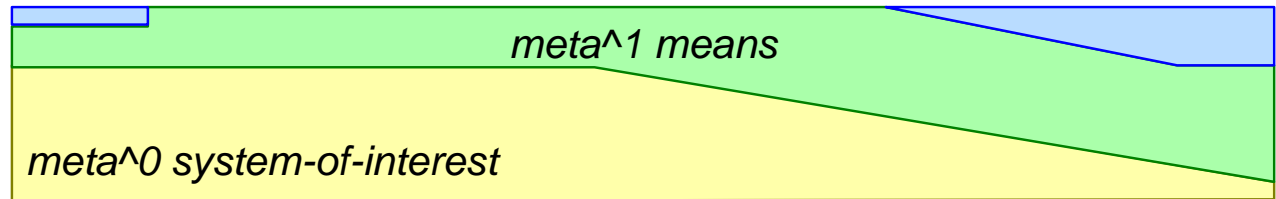
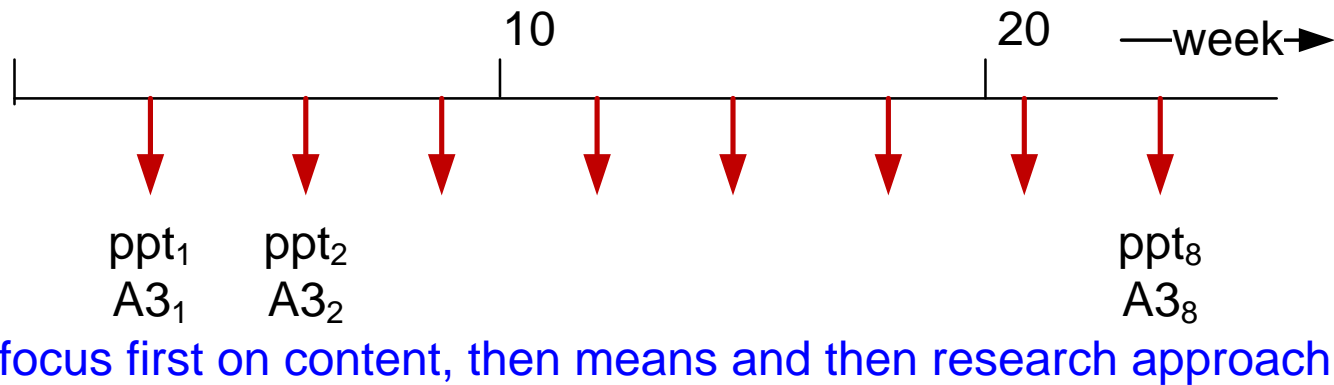
who

references, e.g. URLs; make electronic copy of any relevant material

all "raw" data, e.g. submitted questionnaires

all intermediate data, e.g. spread sheets with version numbers and dates

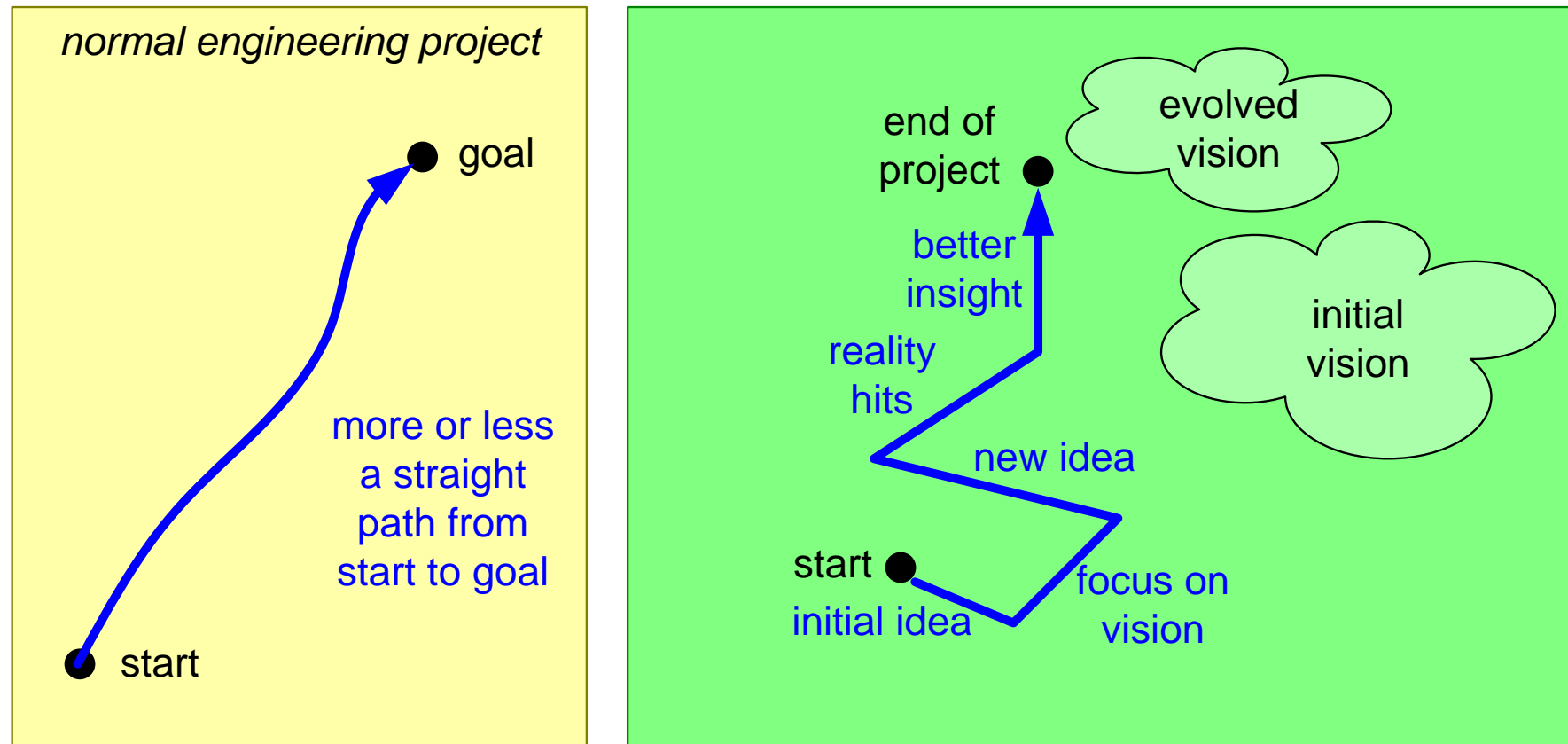
# Discuss Regularly With Company Supervisor





# The Nature of Research Projects

*Research is an adventurous journey, be perceptive and see where it goes*



*Some students in the past called it a rollercoaster....*

# Systems Engineering Course Research Methods; Assignments

by *Gerrit Muller*      University of South-Eastern Norway

e-mail: [gaudisite@gmail.com](mailto:gaudisite@gmail.com)

www.gaudisite.nl

# Abstract

This course teaches research methods for systems engineering and related disciplines, such as industrial economy, engineering management, innovation, and technology management. This field of research needs research methods combining the traditional scientific methods ("hard") and methods from social sciences ("soft").

The course prepares students for their master thesis.

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version: 1.2



This course is a joint development of

Kristin Falk

Satya Kokkula

Elisabet Syverud

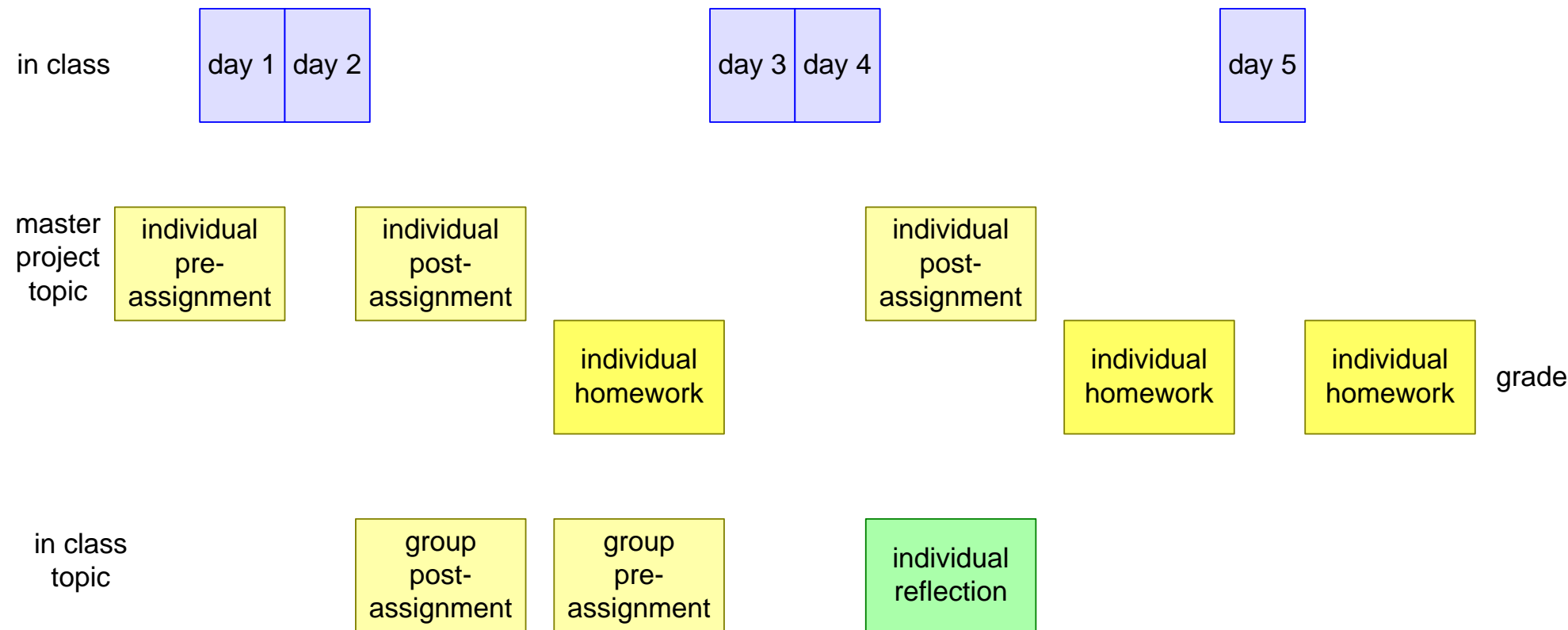
and Gerrit Muller

# Research Methods Course Pre-assignment

---

- Determine a topic for the master project
- Position the topic in its context (e.g. in your company, in ongoing projects)
- Discuss the topic with its stakeholders
- Try to formulate the line of reasoning:
  - problem, goal, envisioned solution, rationale, open research questions

# Flow of Assignments



# What Specific Problem Triggers this Research?

---

- Describe what problem triggers your research
- Be as specific as possible, for instance asking:
  - Why, what, how, who, when, where
- If you find it difficult to describe the problem, then start with listing symptoms and challenges, or identifying dilemmas

- Who are the stakeholders related to this problem
- What can you ask them to explore the problem
- What can you tell them to introduce your research
- Transform the answers into a script for interviews of stakeholders

# Formulate an Initial Set of Research Questions

---

- Transform the **problem statement** into a main **research question**
- What sub-questions will help you to answer the main research question?

Good research questions are **open questions**, e.g. allowing an answer in terms of how well, how much, etc.

You typically need one main question and **3 to 5** sub-questions.

Make all questions as **specific** as possible. The main question may invite some generalization.



# Feasibility of this Study

---

- Define the scope of the research, fitting in the available time and effort
- What do you need (e.g. information, contacts, access to people, tools, ...) to perform the study?
- What risks do you see for the research?

- Use the research questions to determine 5 to 10 key words or phrases
- Search for relevant literature
- Identify ~3 potentially interesting papers
- Make an initial assessment of these 3 papers

Keep notes on all papers you find

# Refine Literature Search

---

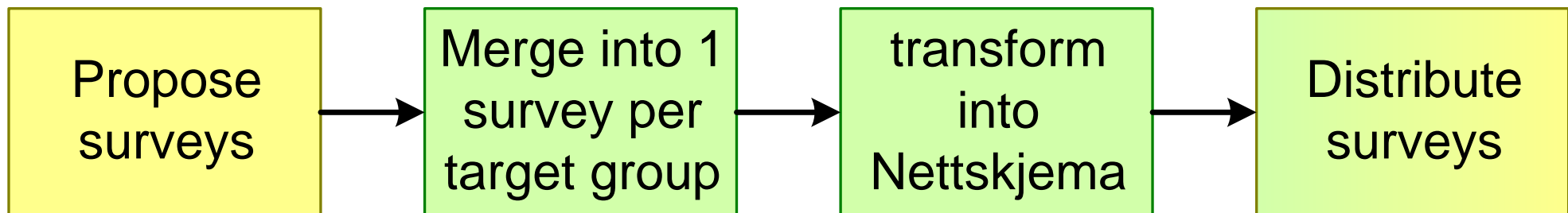
- Refine the 5 to 10 key words or phrases
- Look for literature reviews
- Look for founding papers
- Use these to search for relevant papers
- Order on relevancy based on abstract

Keep notes on all papers you find

# Propose Survey Approach

---

- Define the target groups
- For each target group
  - Formulate survey questions
  - Propose format per question, e.g. free text, range, Likert scale



# Make an Initial Research Design

---

- What will you do, when and where with who?
- What will you look for and look at?
- How can you analyse what you did and observed?
- How will this help you to answer the research questions?

# Block 1 Post-assignment Group

---

- Finish the survey
- Distribute the survey to enough people to get a response of at least 10 respondents.
- Collect the results one week before Block 2.

# Block 1 Post-assignment Individual

---

- Refine the topic for the master project
- Position the topic in its context (e.g. in your company, in ongoing projects)
- Discuss the topic with its stakeholders
- Reformulate the line of reasoning:
  - problem, goal, envisioned solution, rationale, open research questions

# Homework Block 1

For the individual master project topic:

	effort
<ul style="list-style-type: none"><li>• initial interview and/or survey</li><li>• initial problem analysis</li></ul>	30%
<ul style="list-style-type: none"><li>• literature review Body of Knowledge</li><li>• search secondary data sources</li></ul>	60%
<ul style="list-style-type: none"><li>• read Research Methods paper</li><li>• elaborate research design</li></ul>	10%

Submit a 5 to10 page report with the above content; **maintain a detailed logbook!**

Refresh your statistics, for instance <https://towardsdatascience.com/the-5-basic-statistics-concepts-data-scientists-need-to-know-2c96740377ae>



# Analysis of the Survey Data

---

- Download the Excel spreadsheets with survey data
- Discuss what you can do with this data for analysis
- Discuss how you can use this data

# Relate the Data and the Research Questions

---

- Take the research questions that you defined in the post-assignment.
- Does the survey give you any new insights in the research questions?
- Do you want to adapt the research questions?
- Do you want to run another survey? If so, what are the questions for the new survey?

# Revisit Individual Master Project

---

- Revisit your research design
- What data do you need?
- How can you collect that data?
- What are the main challenges for your master project?

# Assess your Current Project Definition

---

- How good is your scope [1 = very poorly defines.. 5 = very well defined]
- How good are your research questions [ same 1 to 5]
- How confident are you that you can execute the project [1 to 5]
- What are the main hurdles?

- Analyze the data statistically
- Look for overall distribution and for correlations
- Capture results on a PowerPoint slide

Upload the PowerPoint file to Canvas

# Re-iterate the Research Questions

---

- Classify your research questions according to the meta-levels and their scope
- Are the research questions specific enough?
- Do you have a logical build-up of the research questions?
- Do you have a way to find answers?

# Discuss the validity of your results

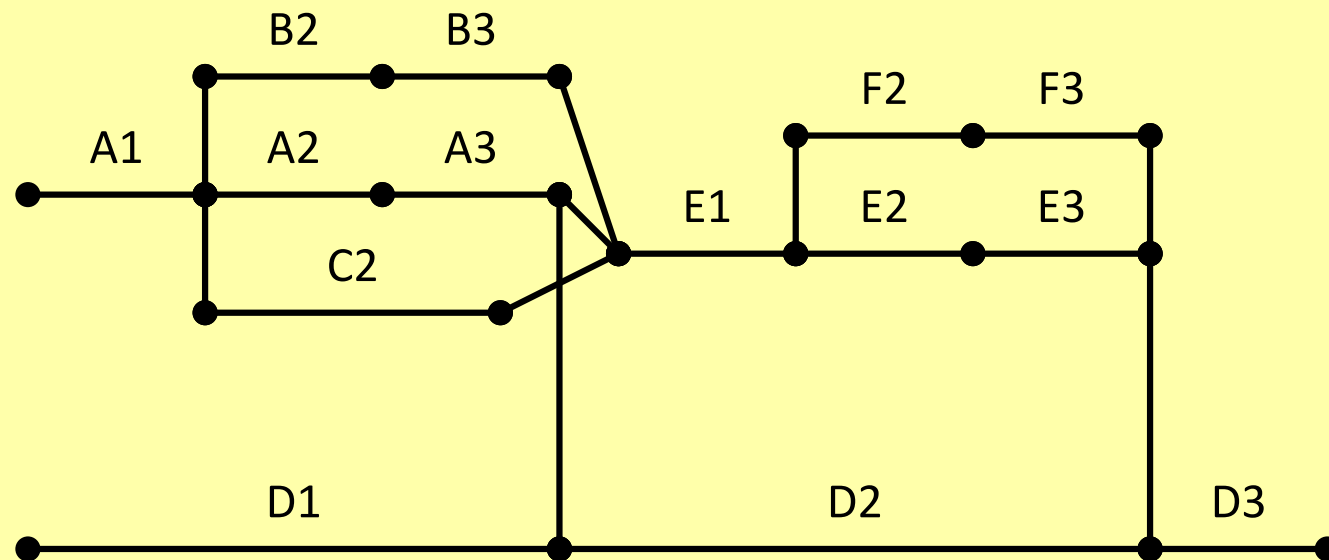
---

- Only from statistical perspective
- Including the survey process
- Capture results on a PowerPoint slide

Upload the PowerPoint file to Canvas

# Make a PERT plan for Master Project Execution

- Strive for >20 activities
- Show dependencies





# Assess your PERT plan

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- How many activities did you define so far?
- How concrete are the activities? [1 = highly generic, 5 is very specific (e.g. system, phase, stakeholder, properties, etc. defined)]

# Make a Book Plan for your Course Paper

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- Define the sections
- Define the subsections
- Define the content per (sub)section in keywords
- Define the size of subsections in #pages (e.g.  $\frac{1}{4}$  page, 3 pages)

# Report Main Book Plan Sizes

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How many pages do you plan for:

- Line of reasoning
- Literature survey
- Research design
- Expected results

- Write a brief reflection on the in-class assignment:
  - What are the main findings?
  - How did you get to these findings?
  - What did you learn from doing the in-class assignment?

max 2 A4s

# Block 2 Post-assignment Individual

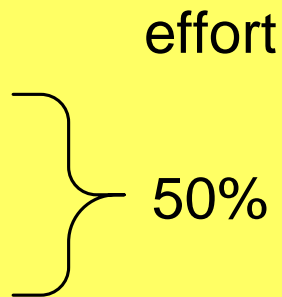
---

Maximum two A4 pages in total

- Update the line of reasoning for your master project topic, including the research questions, according to your current understanding.
- Write down your research plan, include
  - Research design
  - Research method(s)
  - Explain how to collect what data
  - Explain how to analyze data

# Homework Block 2

For the individual master project topic:

- continue literature review
  - write critic of 2..3 papers
  - identify challenges and risks in problem definition 15%
  - make research design more concrete 30%
  - make book plan for the course paper 5%
- 

Submit a 10 to 15 page report with the above content

maintain a detailed logbook!

# Write an Abstract of your Course Paper

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Write an abstract

in 3 paragraphs

use 2 sentences per paragraph

100..150 words in total

annotate the book plan of the Research Methods paper with keywords for

- content
- scope



# Make a Diagram Visualizing the Research Design

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Make a diagram to visualize the research design, e.g.

- the research actions
- the collected data
- the results from the analysis

for instance in the form of a flow diagram

# Final Homework

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write a course paper, as an academic paper of ca 15 pages, containing:

- title use the template:
- abstract (100 to 150 words) [ITM5000-Master Thesis-template.doc](#)
- introduction (context, line of reasoning)
- literature survey (of about 10 publications)
- research design
- discussion (risks, expected results)
- conclusion

and add appendices (which do not count for the 15 pages)

- an execution (PERT) plan
- a book plan for the final paper of the master project

# Systems Engineering Course Research Methods; Material

by *Gerrit Muller*    University of South-Eastern Norway-NISE

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## Abstract

This module provides links to the course material, both the core material and elective material.

### Distribution

This article or presentation is written as part of the Gaudí project. The Gaudí project philosophy is to improve by obtaining frequent feedback. Frequent feedback is pursued by an open creation process. This document is published as intermediate or nearly mature version to get feedback. Further distribution is allowed as long as the document remains complete and unchanged.

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and Gerrit Muller

*core*

Systems Engineering Course Research Methods; Framework

<http://www.gaudisite.nl/info/SEcourseResearchMethodsFramework.info.html>

*optional*

TBD

# Problem Exploration

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*core*

Systems Engineering Course Research Methods; Problem Exploration

<http://www.gaudisite.nl/info/SEcourseResearchMethodsProblemExploration.info.html>

*optional*

TBD

*core*

Literature why, what, how, and Practicalities by K. Falk

[https://gaudisite.nl/SECRM\\_Falk\\_LiteratureWhyWhatHowAndPracticalities.pdf](https://gaudisite.nl/SECRM_Falk_LiteratureWhyWhatHowAndPracticalities.pdf)

*optional*

TBD

## *core*

Research in Systems Architecting

<https://gaudisite.nl/info/ArchitectingResearchMethod.info.html>

Systems Engineering Research Methods

<https://gaudisite.nl/info/SEresearchMethods.info.html>

Systems Engineering Research; Examples of Flow and Methodology

<https://gaudisite.nl/info/SEresearchExamples.info.html>

## *optional*

Systems Engineering Research Validation

<https://gaudisite.nl/info/SEresearchValidation.info.html>

Validation of Systems Engineering Methods and Techniques in Industry

[http://www.gaudisite.nl/CSER2012\\_Muller\\_validationSEinIndustry.pdf](http://www.gaudisite.nl/CSER2012_Muller_validationSEinIndustry.pdf)

Systems Engineering Research Methods

[https://www.gaudisite.nl/CSER2013\\_Muller\\_SEresearchMethods.pdf](https://www.gaudisite.nl/CSER2013_Muller_SEresearchMethods.pdf)

Application and Validation of Systems Engineering Methods and Techniques in Practice

[https://gaudisite.nl/NOVA\\_Muller\\_AdvancesInSystemsEngineeringResearch.pdf](https://gaudisite.nl/NOVA_Muller_AdvancesInSystemsEngineeringResearch.pdf)

Master Project Papers <https://www.gaudisite.nl/MasterProjectPapers.html>



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Statistics by E. Syverud

[https://gaudisite.nl/SECRM\\_Syverud\\_Statistics.pdf](https://gaudisite.nl/SECRM_Syverud_Statistics.pdf)

*optional*

TBD

*core*

Research Ethics USN by S. Kokkula

[https://gaudisite.nl/SECRM\\_Kokkula\\_ResearchEthicsUSN.pdf](https://gaudisite.nl/SECRM_Kokkula_ResearchEthicsUSN.pdf)

*optional*

TBD

*core*

Systems Engineering Course Research Methods; Language and Style of Academic Writing

<https://gaudisite.nl/info/SEcourseResearchMethodsWritingLanguage.info.html>

Systems Engineering Course Research Methods; Structure of Academic Papers

<https://gaudisite.nl/info/SEcourseResearchMethodsWritingStructure.info.html>

*optional*

TBD