THE FUTURE OF SYSTEMS ENGINEERING IN THE DUTCH HIGH TECH INDUSTRY

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6 October 2022

Powered by industry, academia and TNO

ESI

OUTLINE

1. **Engineering:** ***Dutch High Tech***
2. **Systems Engineering:** ***In The Netherlands***
3. **Based Systems Engineering:** ***Methodology innovation***
4. **Model Based Systems Engineering:** ***Value for Dutch High Tech***
5. **SE education in The Netherlands:** ***National Growthfund project***

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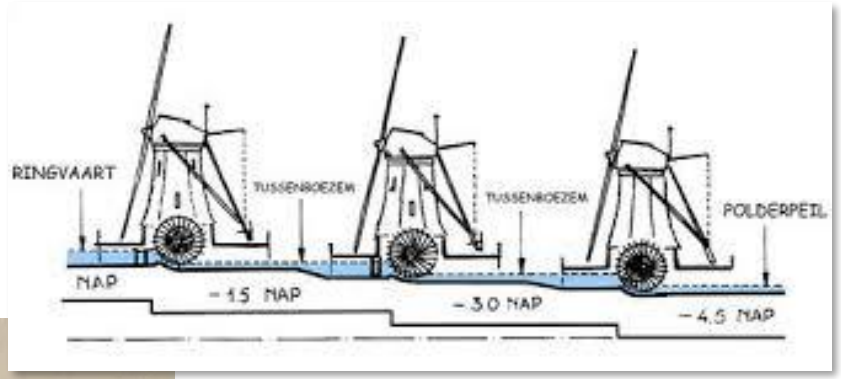
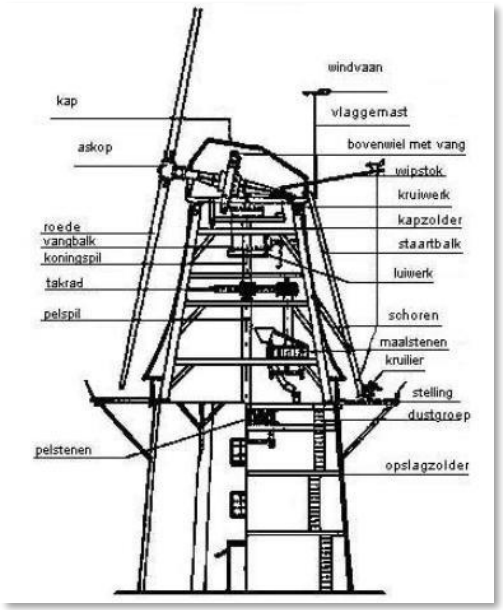
ENGINEERING

ANNO 1612


RINGVAART
TUSSENBOEZEM
TUSSENBOEZEM
POLDERPEIL
NAP
-1.5 NAP
-3.0 NAP
-4.5 NAP


Inpoldering van de Beemster


windvaan
kap
vlaggemast
askop
bovenwiel met vang
wipstok
kruiwerk
kapzolder
roede
vangbalk
staartbalk
koningspil
luiwerk
takrad
pelspil
schoren
maalstenen
kruilier
stelling
dustgroep
pelstenen
opslagzolder

THE (DUTCH) HIGH-TECH INDUSTRY

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Semiconductor manufacturing equipment

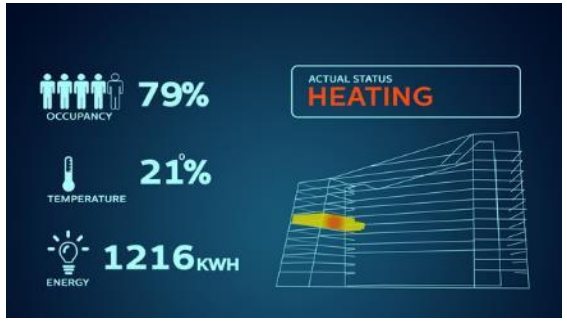
Medical systems

Food processing

Agricultural robots

Traffic management

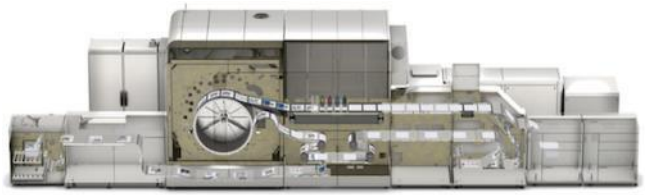
Electron microscopes



Building control

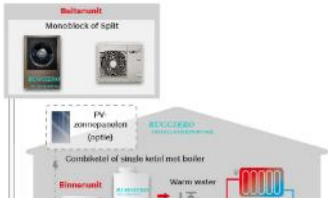
Robotized warehousing

Combat management systems



Industrial printers

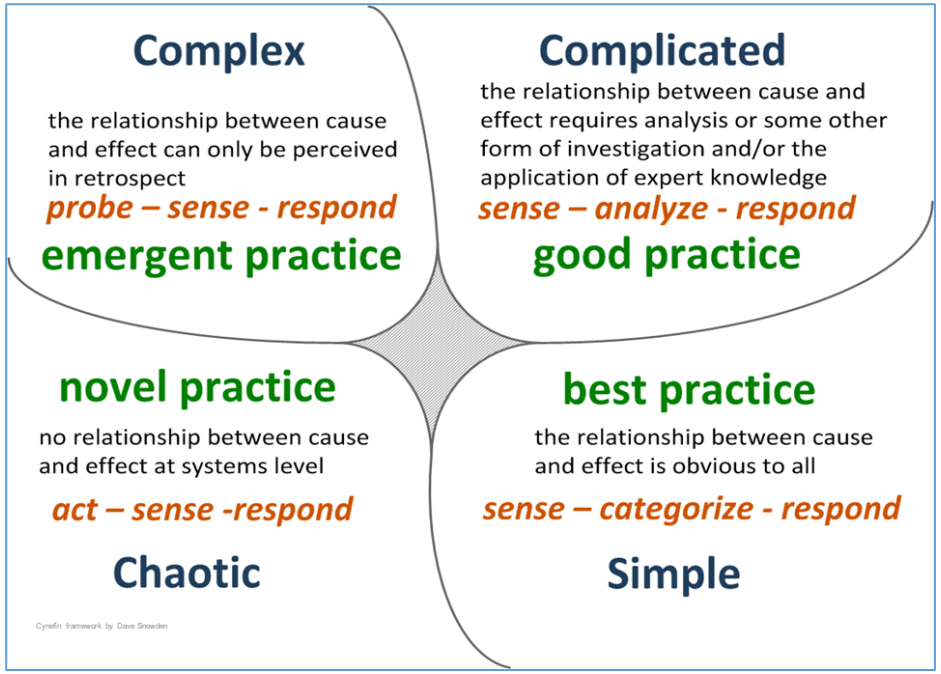
Automotive



Residential heating/cooling

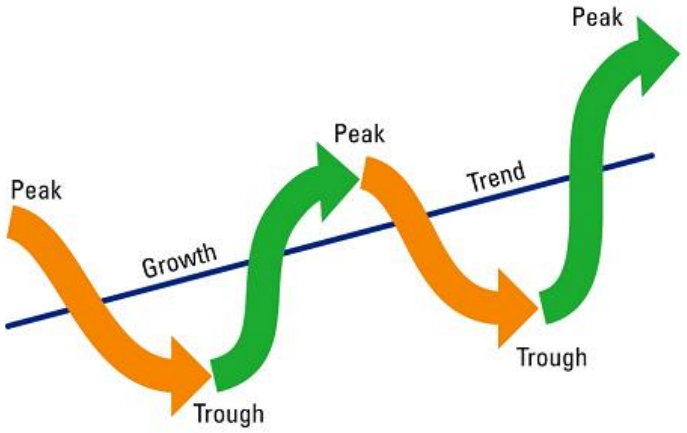
High-tech industry characteristics

- **Globalization** has introduced a change in customer mix and entries into emerging economies.
- **Global diversification** has become yet another challenge
- Increasingly emphasis on providing services, content and interoperability around their products: **open systems, solution selling**
- The products, as well as the context in which the products operated have become highly **digitalized**
- De-verticalized businesses, **increasingly tightly integrated supply chains**
- **Total life-cycle business**, i.e. the sales of new products combined with services to installed products, is an ever more important revenue model
- **Effective collaboration** among globally dispersed design teams and with external partners has become a necessity

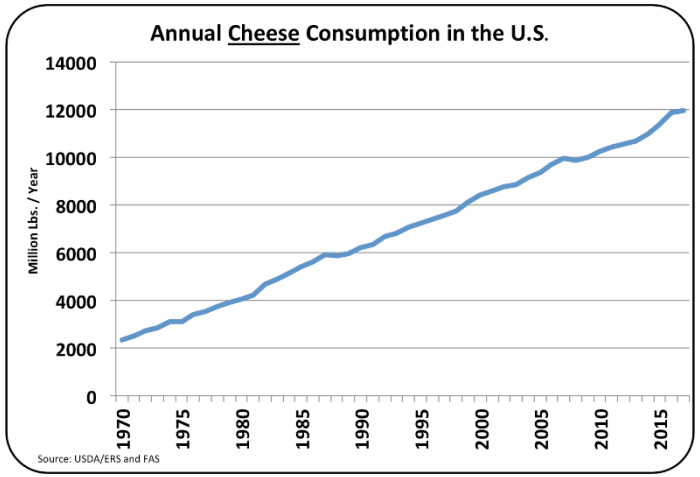


HIGH TECH HAS BECOME A PRIMARY NECESSITY OF LIFE

Electronics in 90's and 00's
Cyclic fluctuations



Electronics today
Steady and strong growth



"Kaas marcheert altijd"

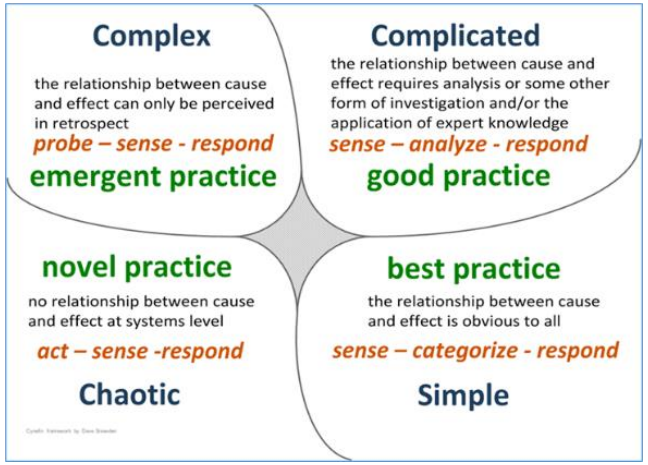
SYSTEMS ENGINEERING

WHY SYSTEMS ENGINEERING?

- More than just multi-disciplinarity
- Bringing market, business and techological considerations together
- Integral (process) approach
- System Architecture and System Integration competence become increasingly important

SYSTEMS THINKING

The insight that systems cannot be understood by analysis- the properties of the parts can only be understood within the larger context of the whole.

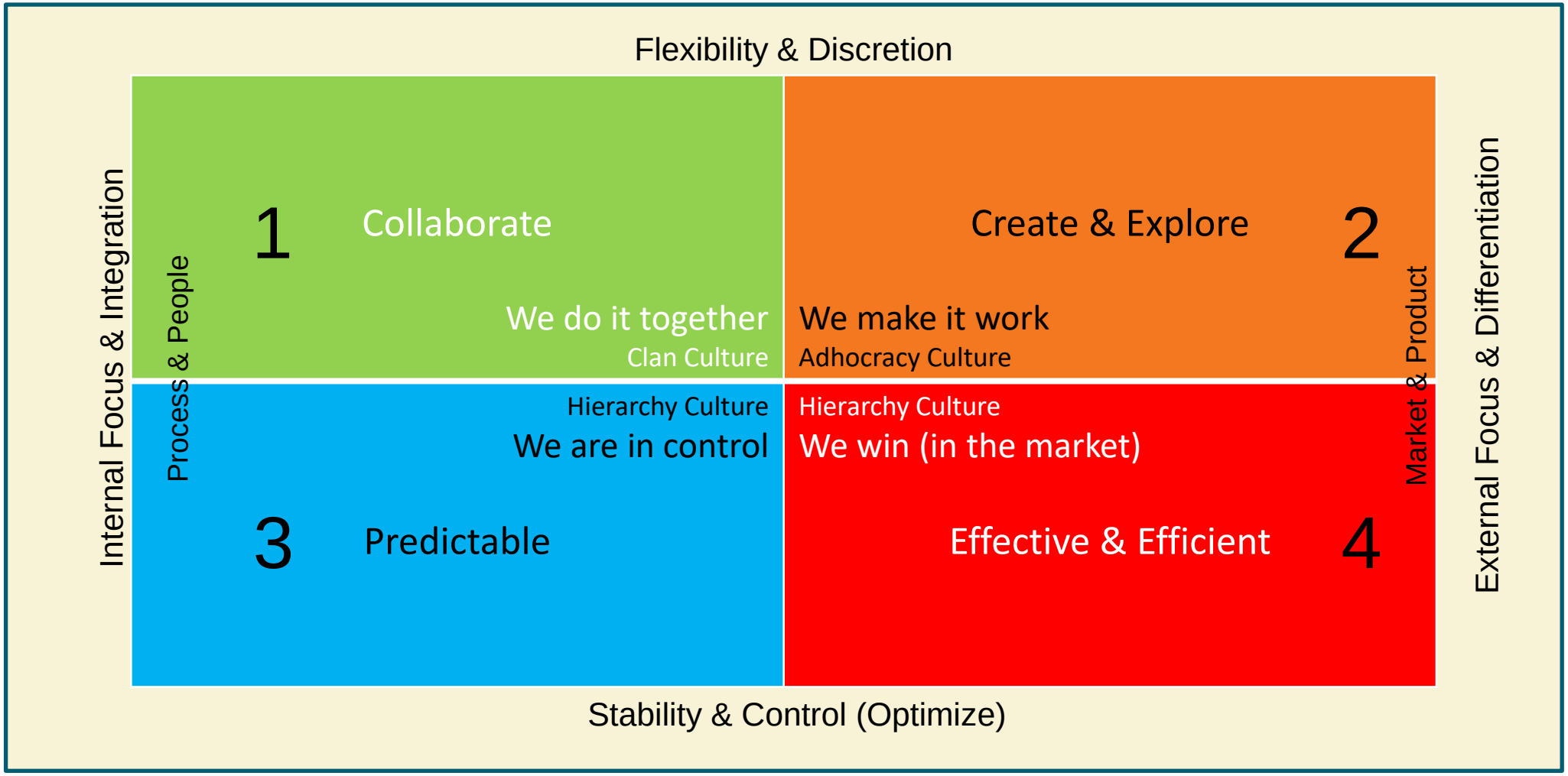


STUDIES INTO SYSTEMS ENGINEERING PRACTICE

The Helix project (SERC): identifying the proficiencies of effective systems engineers.

Blueprint Systems Engineering in Brainport Eindhoven

FOUR TYPES OF CULTURES/VALUES



Inspired by Quinn & Cameron and Insights Discovery

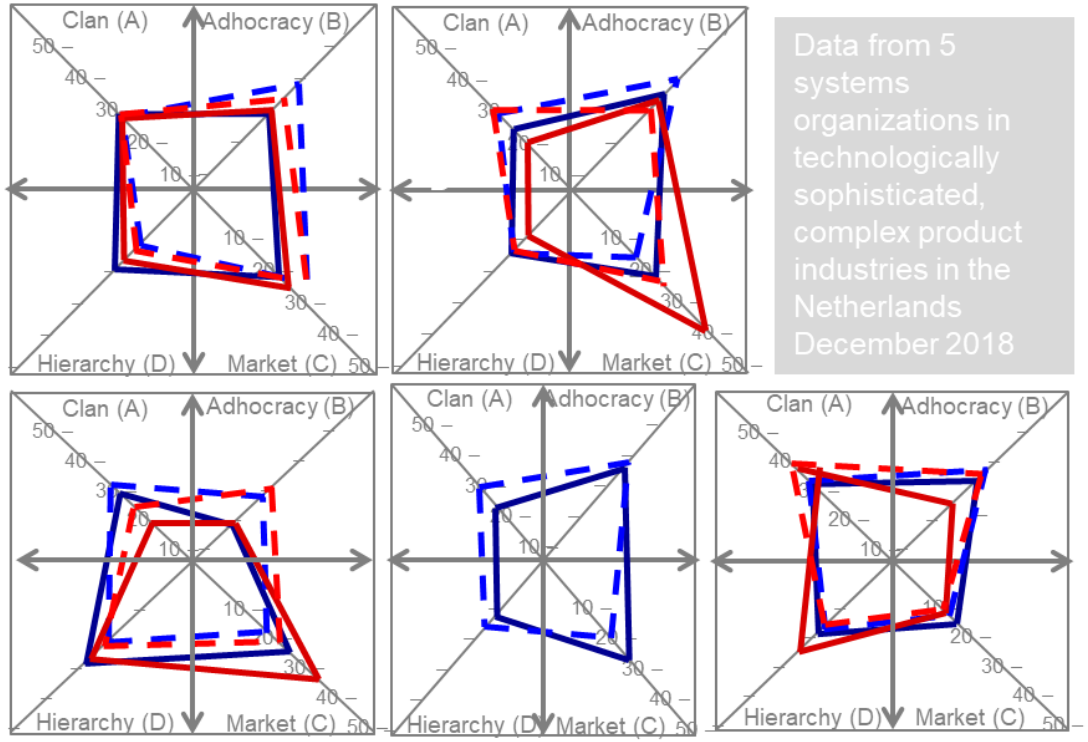
WHAT DRIVES VALUE AND EFFECTIVENESS

Clan culture

Adhocracy culture

Hierarchy culture

Market culture



Data from 5 systems organizations in technologically sophisticated, complex product industries in the Netherlands December 2018

Why The Netherlands?
SERC Helix studies compared cultures

Knowledge is power

Limit stratification

Expect to be challenged

Federation of brilliant people who influence each other for the common good

Process fits the project

Collaboration includes consensus

I talk with people for a living

Leadership: egalitarian vs hierarchial

Influence Without Authority

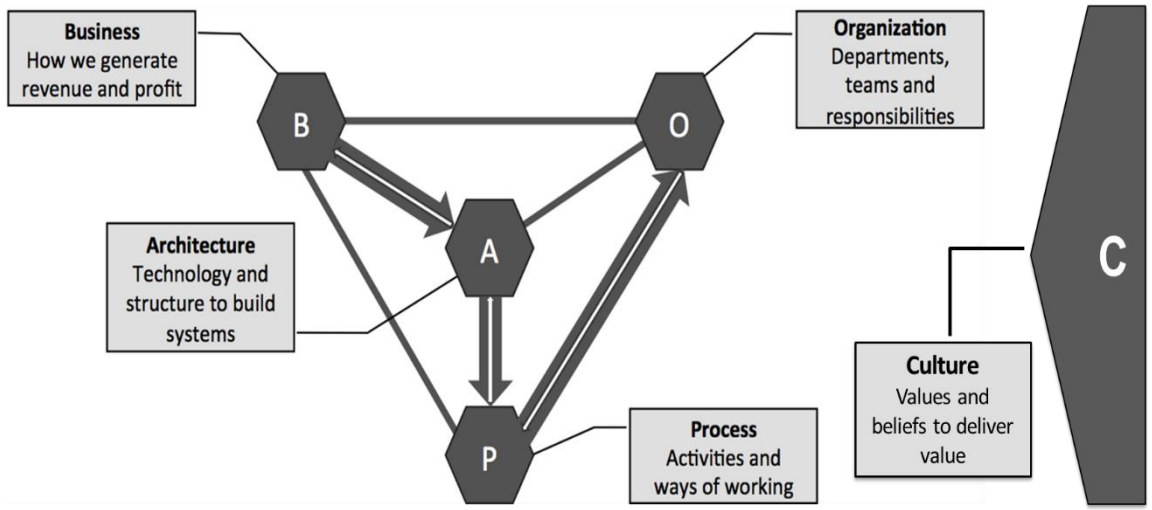
Constructive Debate

Yes, and…

Power comes from order: role, function, organization

Projects fit the process

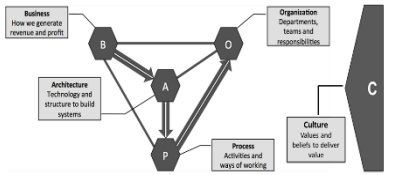
BLUEPRINT SYSTEMS ENGINEERING IN BRAINPORT EINDHOVEN



* SE-BAPO(C) is based on the BAPO model

1. **Business** is the most influential factor. This has to be set up right.
2. **Architecture** reflects the business concerns in system structure and rules.
3. **Process** is set up to develop, build, and maintain the system determined by the architecture.
4. **Organization** should host (the product??) and the process.
5. **Culture** addresses typical shared beliefs and values related to systems engineering.

Blueprint Systems Engineering in Brainport Eindhoven: conclusions



Brainport Business	From low volume, high value B2B mechatronic systems to data driven cyber-physical solutions and services integrated in customer workflows.
Brainport Architecture	System architecture and platforms are key assets to deliver profitable and customized cyber-physical low volume high value solutions and services.
Brainport Process	From an expert centric, content driven SE approach, supported by lightweight processes, methods and tools to a more democratized and explicit, model and data supported, SE approach.
Brainport Organization	Professionals operating in a matrix organization with clear ownership coupled to the system's structure (architecture, product quality, reuse levels, variability mgt.).
Brainport Culture	Systems Engineering in the Brainport region is primarily based on collaboration and creativity and less on control and competition.

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METHODOLOGIES FOR SYSTEMS ENGINEERING

SYSTEMS ENGINEERING IS AN EVOLVING DISCIPLINE

System Architecting and (Systems) Engineering:

From an art to being based on:

- Formalisms
- Techniques
- Methods
- Tools

} methodology

TNO-ESI conducts research into SE methodologies, ensures applicability in real life (in high tech equipment industry) an embeds them into practice

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ESI AT A GLANCE

Mission: ***Embedding leading edge methodologies into the Dutch high-tech systems industry to cope with the ever increasing complexity of their products***

Synopsis

- Foundation ESI started in 2002
- ESI acquired by TNO per January 2013
- ~60 staff members, many with extensive industrial experience
- 7 Part-time Professors
- Working at industry locations

Focus

Managing complexity of high-tech systems

through

- system architecting,
- system reasoning and
- model-driven engineering

delivering

- methodologies validated in cutting-edge industrial practice

Partners

ASML, ThermoFisher Scientific, Philips, Vanderlande, itec, Canon, Thales, TNO, University of Amsterdam, TU Delft, Radboud University Nijmegen, University of Twente., TU/e Eindhoven University of Technology, Capgemini engineering

DIGITAL TRANSITION IN THE HIGH-TECH INDUSTRY

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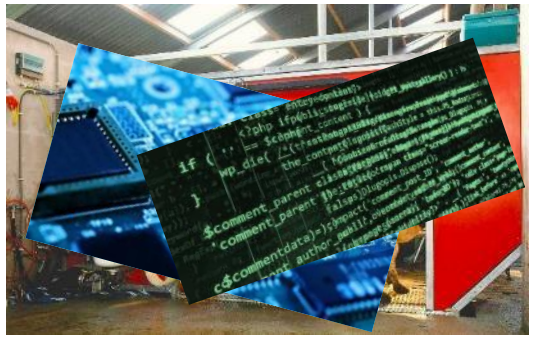
Semiconductor manufacturing equipment

Medical systems

Food processing



Agricultural robots

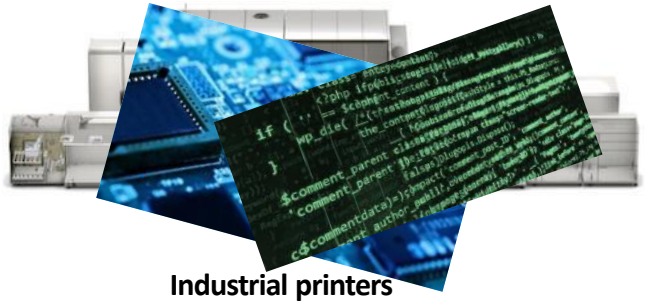
Traffic management

ectron microscopes

Building control

Robotized warehousing

Combat management systems

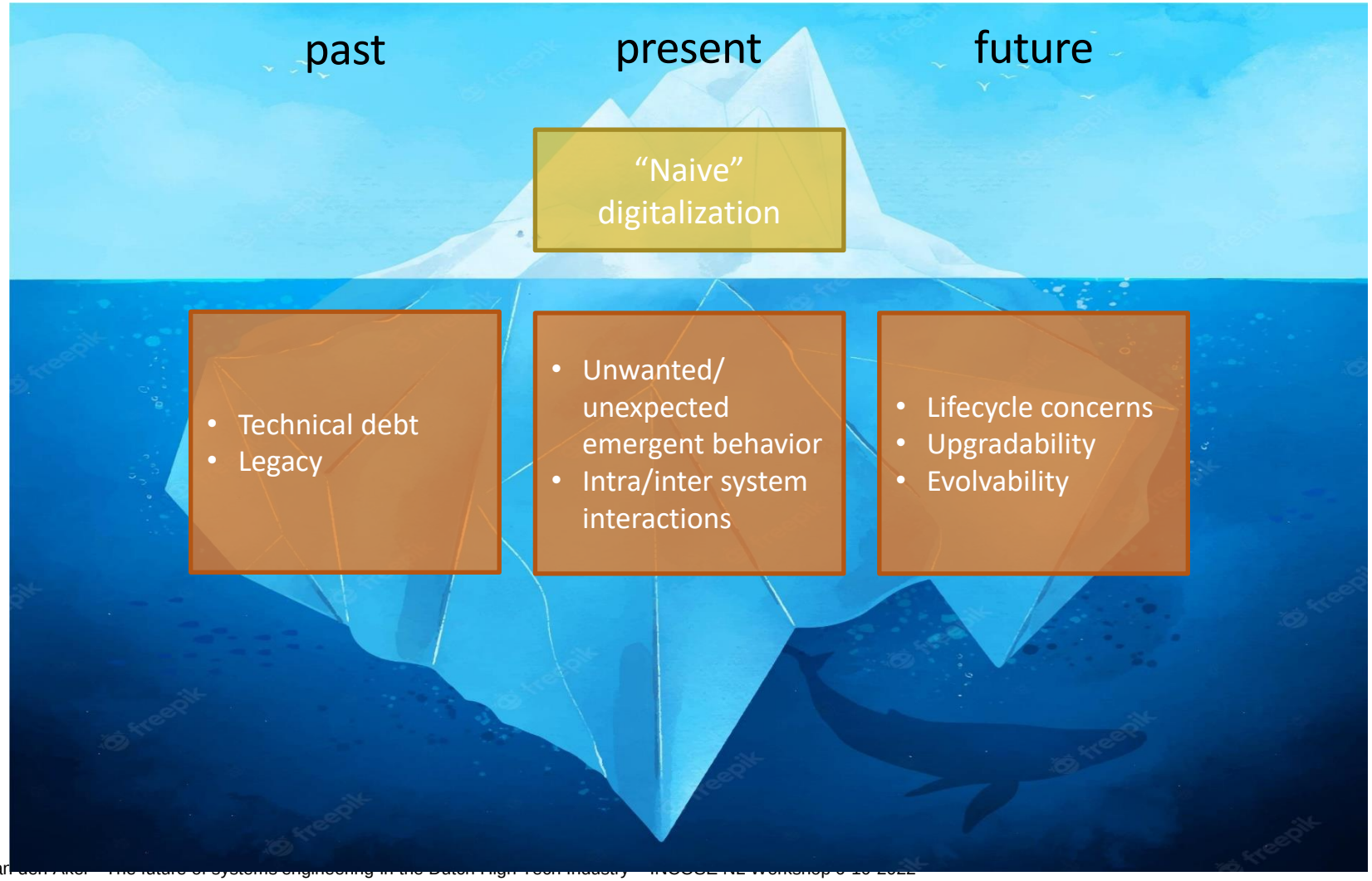


Industrial printers

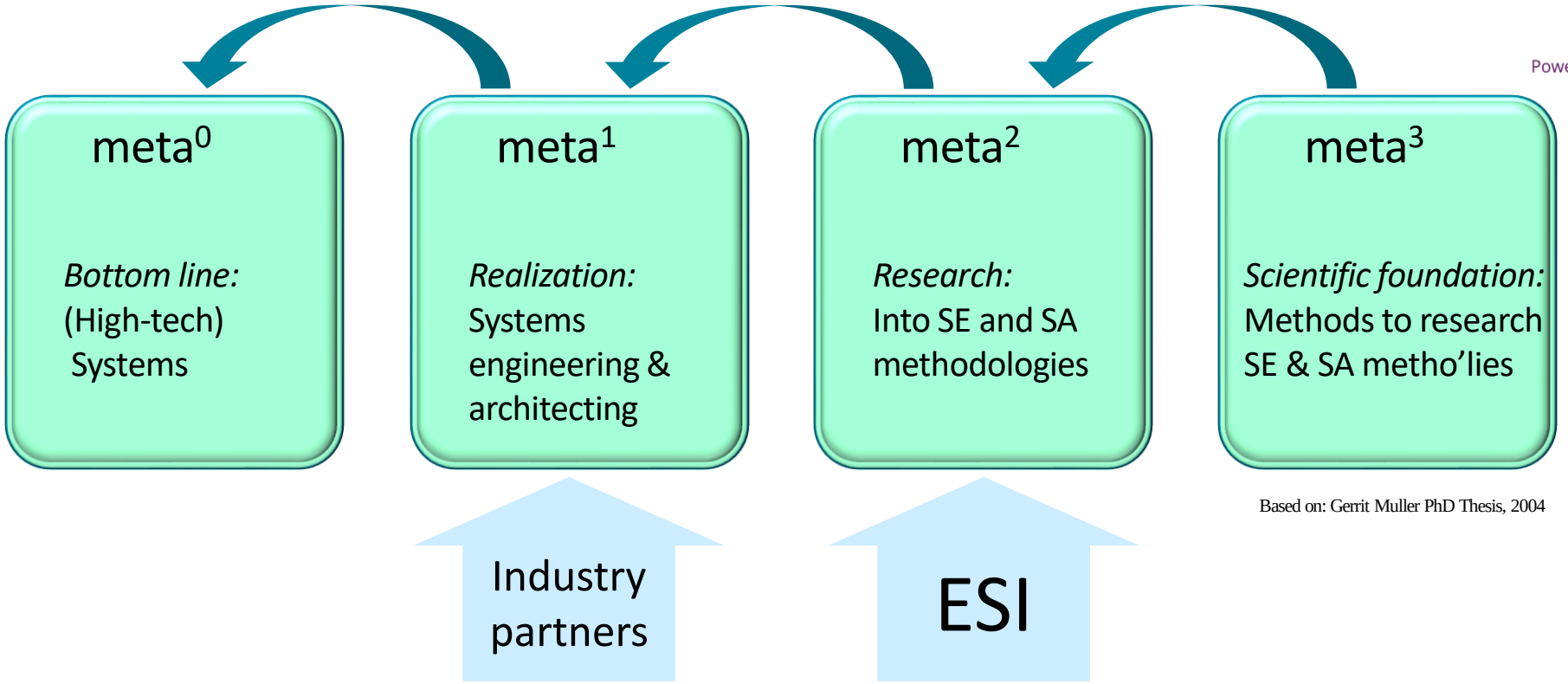
Automotive

Residential heating/cooling

WE NEED TO TALK ABOUT DIGITALIZATION



MENTI QUESTION 1

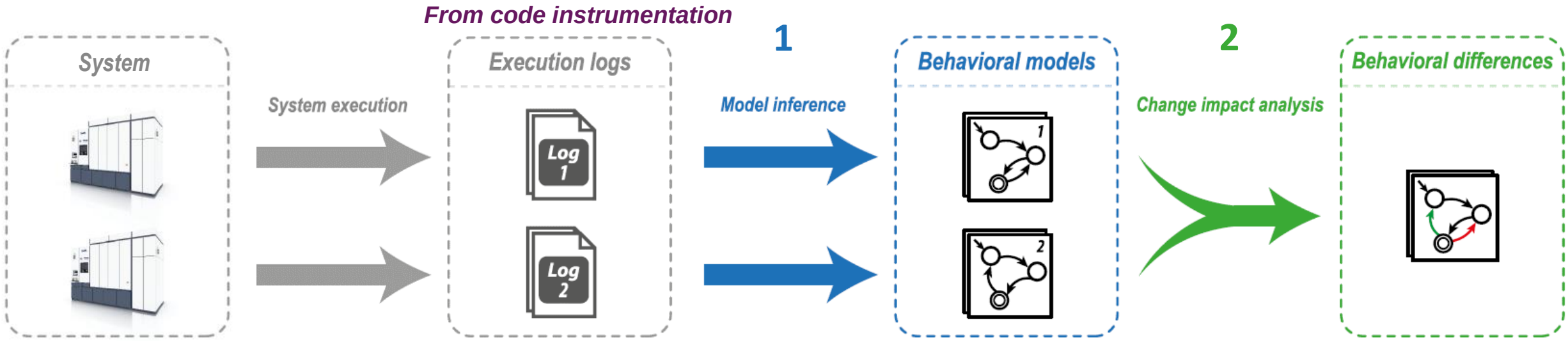


Based on: Gerrit Muller PhD Thesis, 2004

Two examples:

1. **Prevent regression from software changes**
2. **Reasoning from customer value to technical choices**

1. PREVENT REGRESSIONS FOR SOFTWARE CHANGES

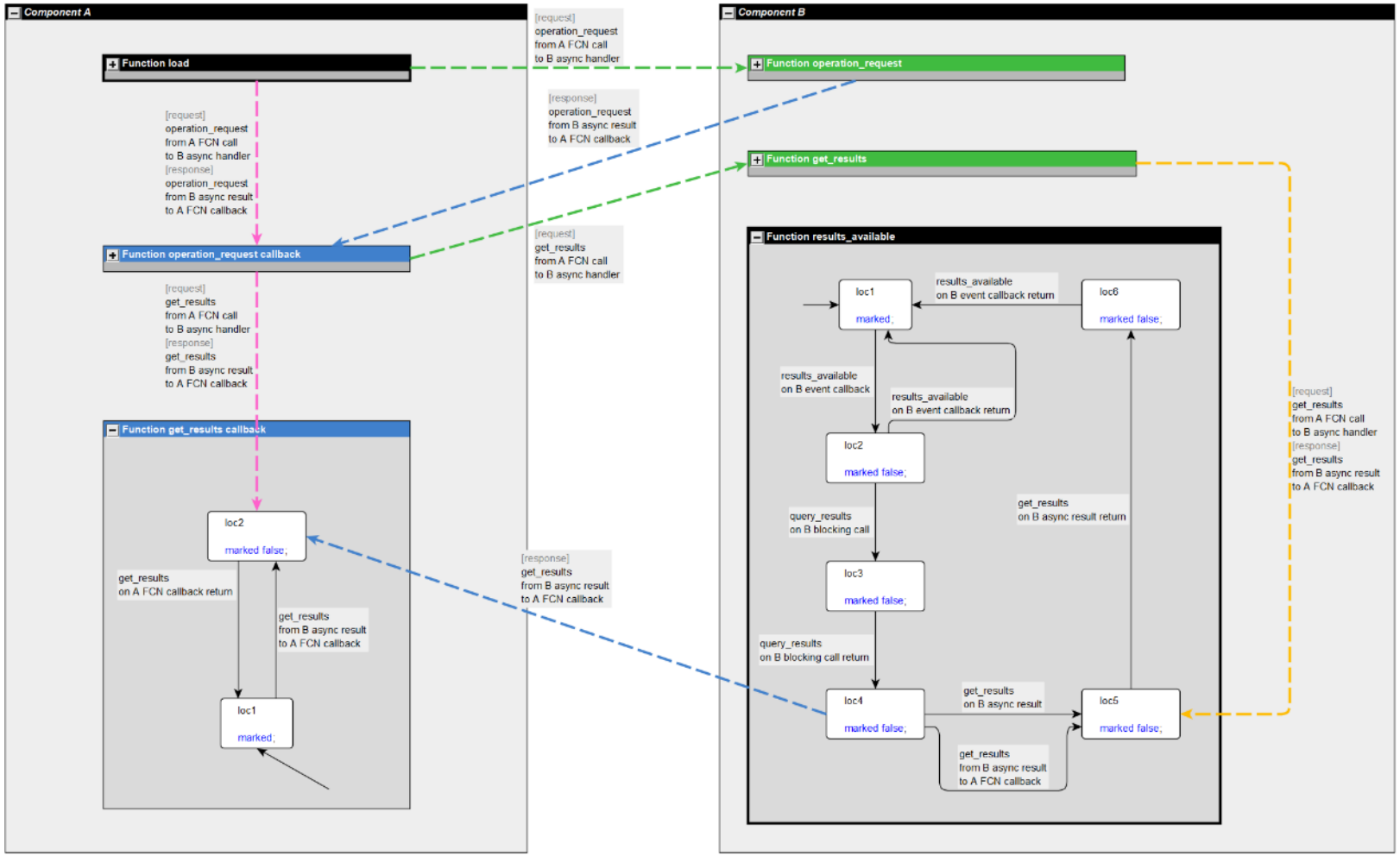


- Automatically infer behavioral models
- Provide insight into software behavior
- Essential for making correct software changes

- Automatically compare behavioral models
- Confirm expected differences and potential regressions
- Quick change impact analysis for system behavior

Improve development efficiency and reduce risks

INFERRED MODELS AT MULTIPLE LEVELS OF DETAIL



“The ability to analyze behavior of our software at a very high level of abstraction, as well as zooming in on the details is extremely cool.”

“You can really see how it behaves, for this configuration.”

CHANGE IMPACT ANALYSIS: QUICKLY IDENTIFY POTENTIAL REGRESSIONS

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- High level expose controller
- One line code change caused a regression

	Before	After
obtain_budget_identifier *(function 1 of 113)*	A	A
check_memory_state *(function 2 of 113)*	A	A
renew_memory_state *(function 3 of 113)*	A	A
get_printer_characteristics *(function 4 of 113)*	A	A
get_component_name *(function 5 of 113)*	A	A
get_current_active_task *(function 6 of 113)*	A	A
set_task_started *(function 7 of 113)*	A	A
load_configuration *(function 8 of 113)*	A	A
store_configuration *(function 9 of 113)*	A	A
perform_plate_assignment *(function 10 of 113)*	A	A
prepare_lens_config *(function 11 of 113)*	A	A
calibrate_level *(function 12 of 113)*	A	A
fixate_measure *(function 13 of 113)*	A	A
signal_printer *(function 14 of 113)*	A	A
prepare_queue *(function 15 of 113)*	A	A
validate_config *(function 16 of 113)*	A	A
obtain_operation_state *(function 17 of 113)*	A	A
operation_queued *(function 18 of 113)*	A	B
report_phase *(function 19 of 113)*	A	A
persist_state *(function 20 of 113)*	A	A
retrieve_error_code *(function 21 of 113)*	A	A
collect_corrections *(function 22 of 113)*	A	A
start_operation *(function 23 of 113)*	A	B
detect_settings_change *(function 24 of 113)*	A	A
sync_measurements *(function 25 of 113)*	A	A
clear_buffers *(function 26 of 113)*	A	A
terminate_measurements *(function 27 of 113)*	A	A
evaluate_measurements *(function 28 of 113)*	A	A
validate_measurements *(function 29 of 113)*	A	A
reset_mark *(function 30 of 113)*	A	A
perform_sensor_corrections *(function 31 of 113)*	A	A
preload_setup_tasks *(function 32 of 113)*	A	A
determine_position *(function 33 of 113)*	A	A
start_synchronization *(function 34 of 113)*	A	A
finalize_configuration *(function 35 of 113)*	A	A

Legend

A	1st behavior for function
B	2nd behavior for function

ASML

CHANGE IMPACT ANALYSIS: INSPECT THE REGRESSION IN DETAIL

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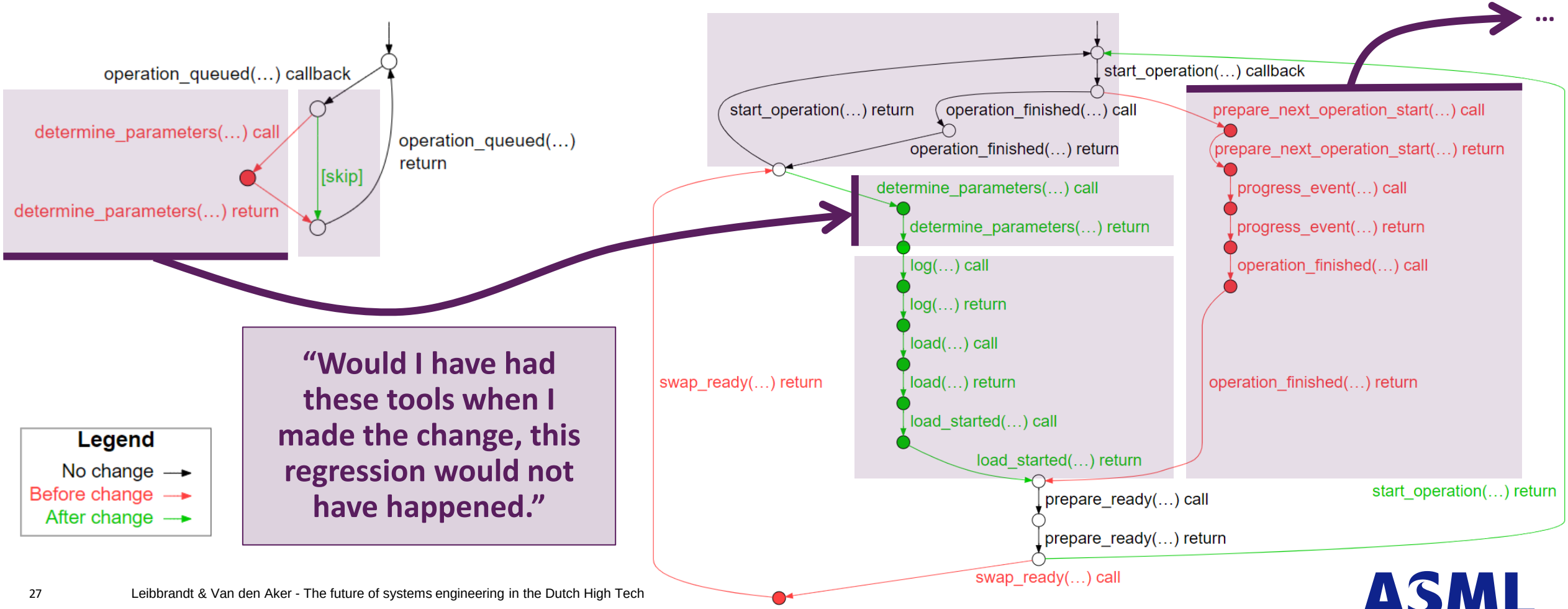
operation_queued callback

start_operation callback



Legend

No change →
Before change →
After change →

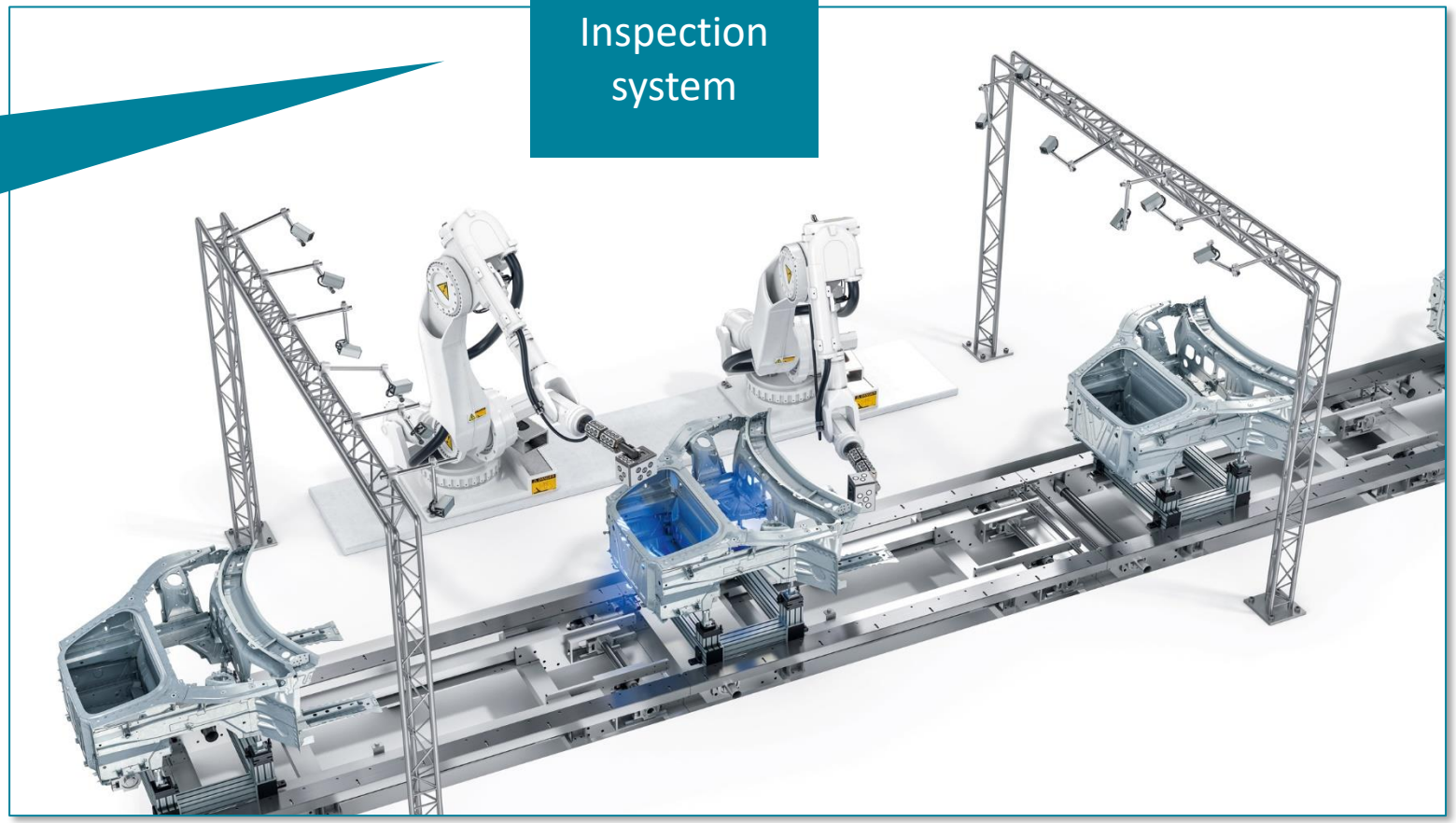
"Would I have had these tools when I made the change, this regression would not have happened."

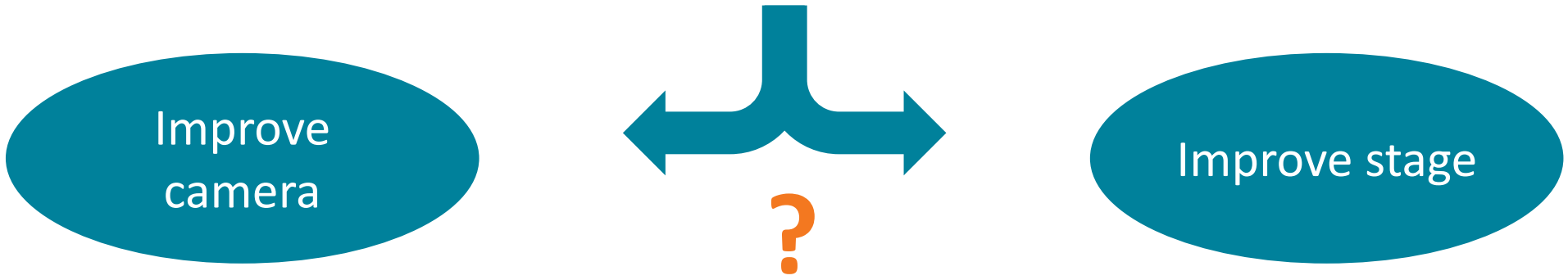
ASML

2. REASONING FROM CUSTOMER VALUE TO TECHNICAL CHOICES

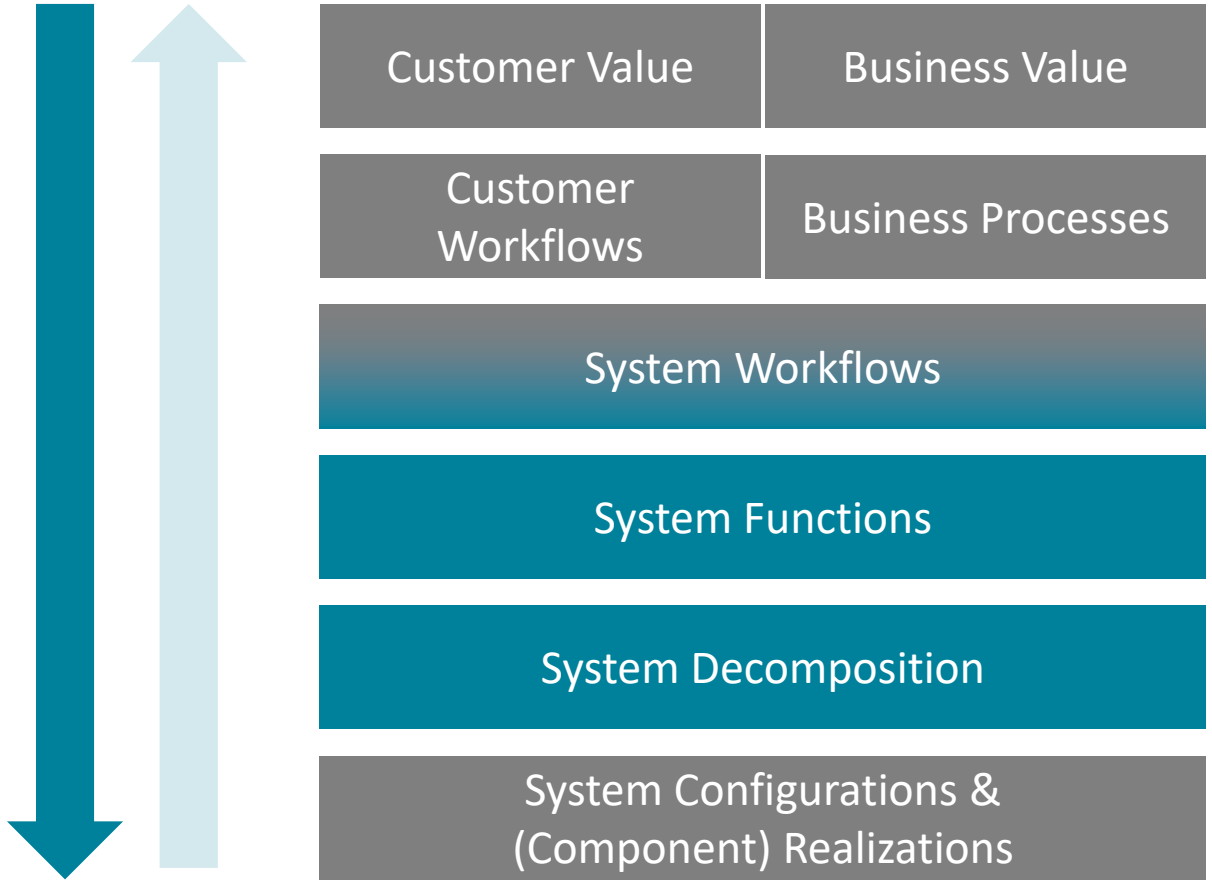
CASE: INNOVATE INSPECTION SYSTEM

Innovate on the stage, or on the camera?

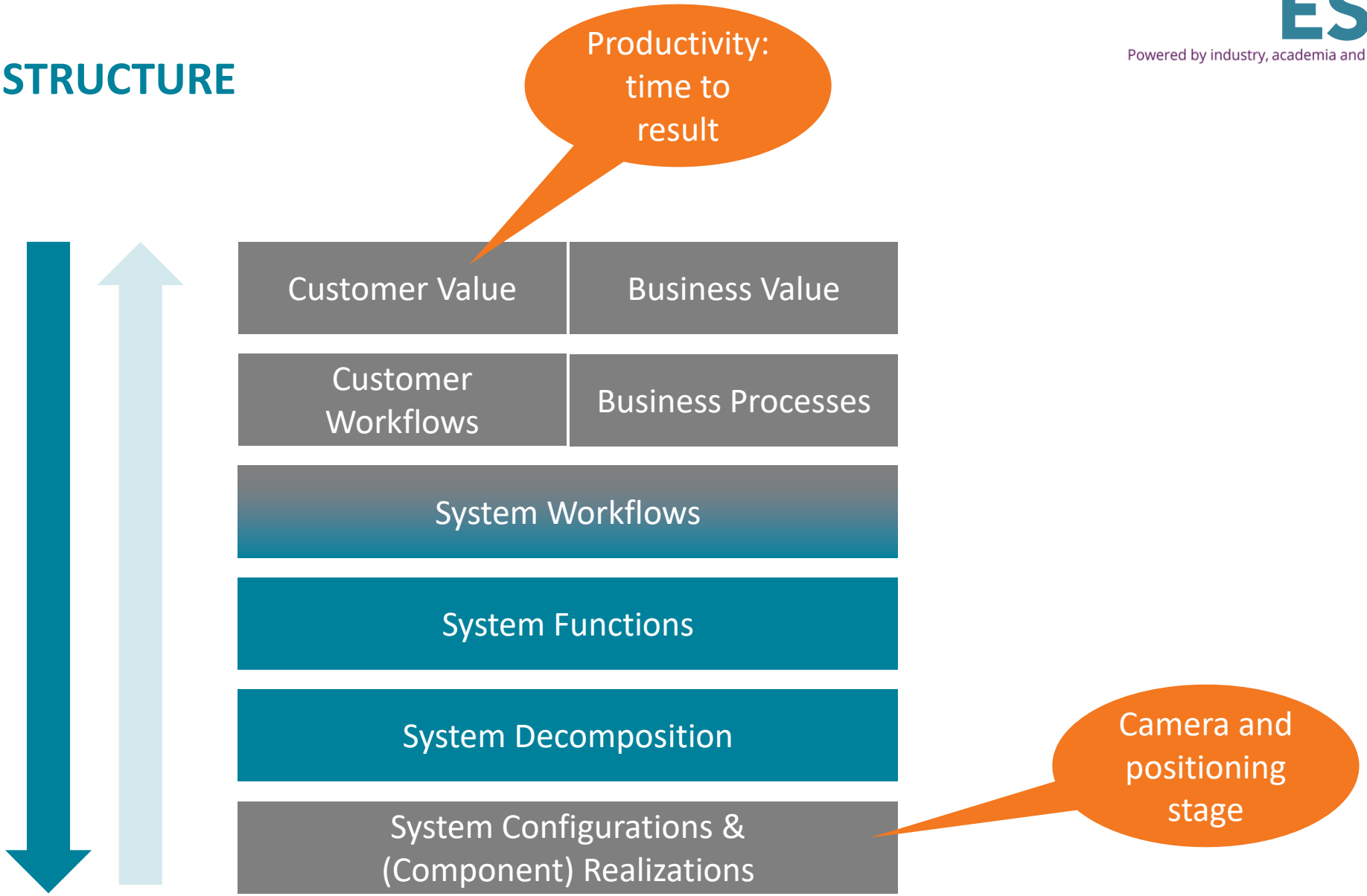



Improve camera
?
Improve stage

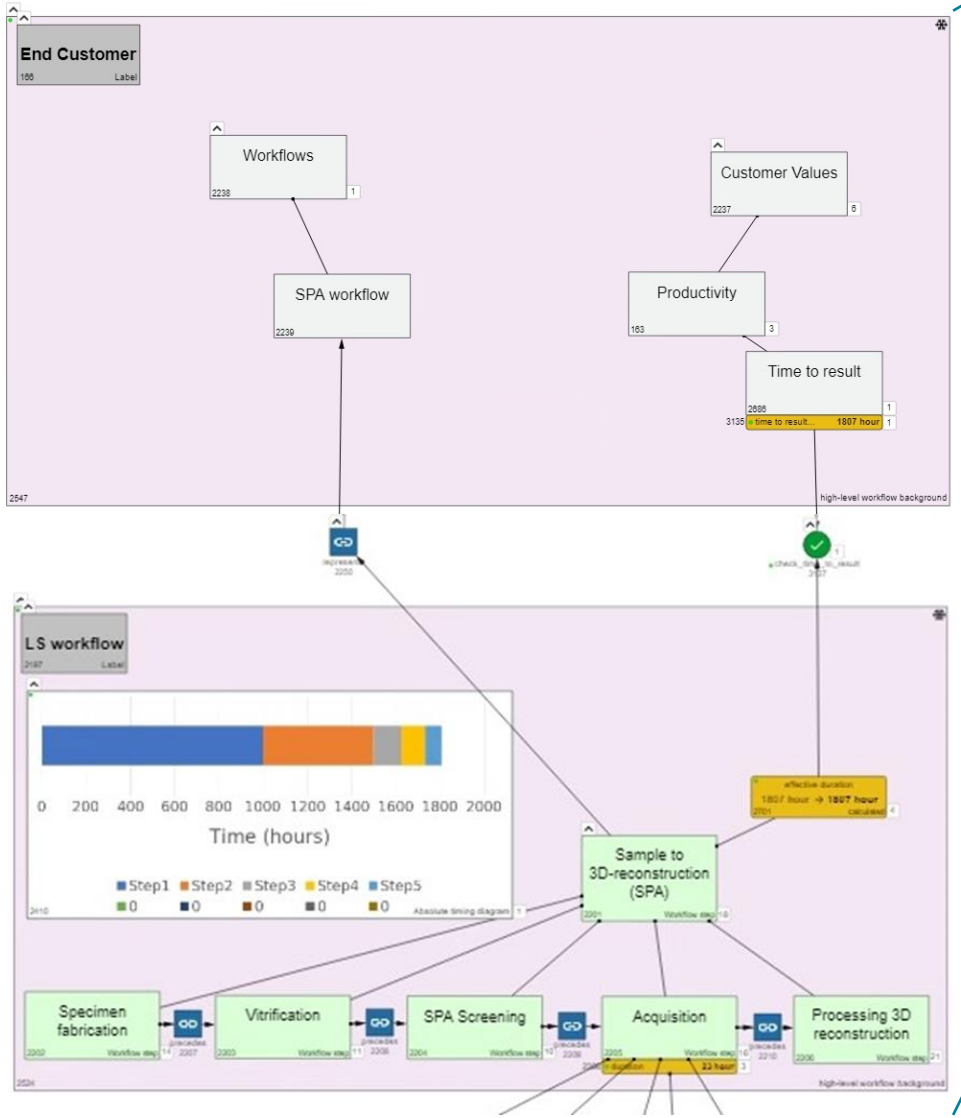
INFORMATION STRUCTURE

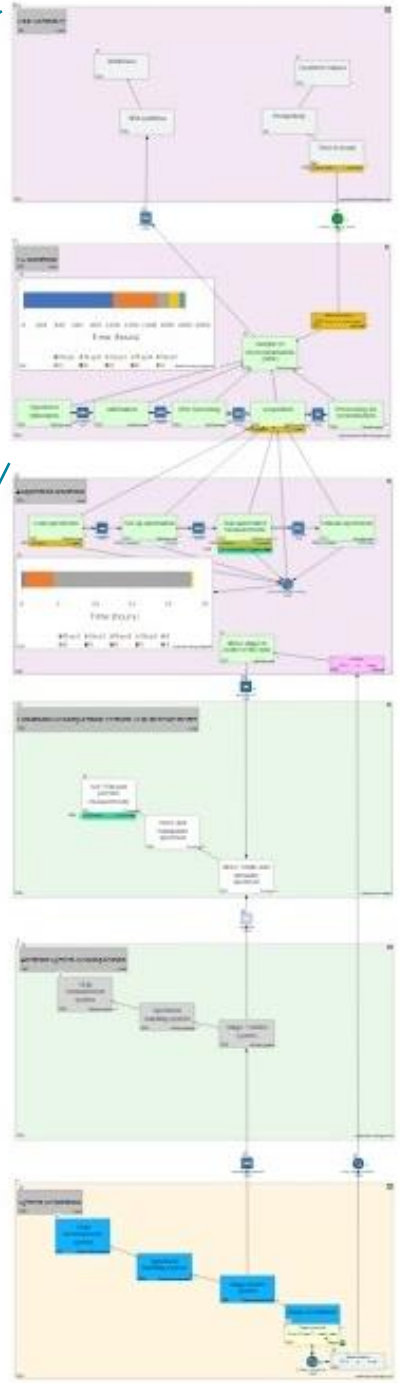


INFORMATION STRUCTURE



DAARIUS METHODOLOGY





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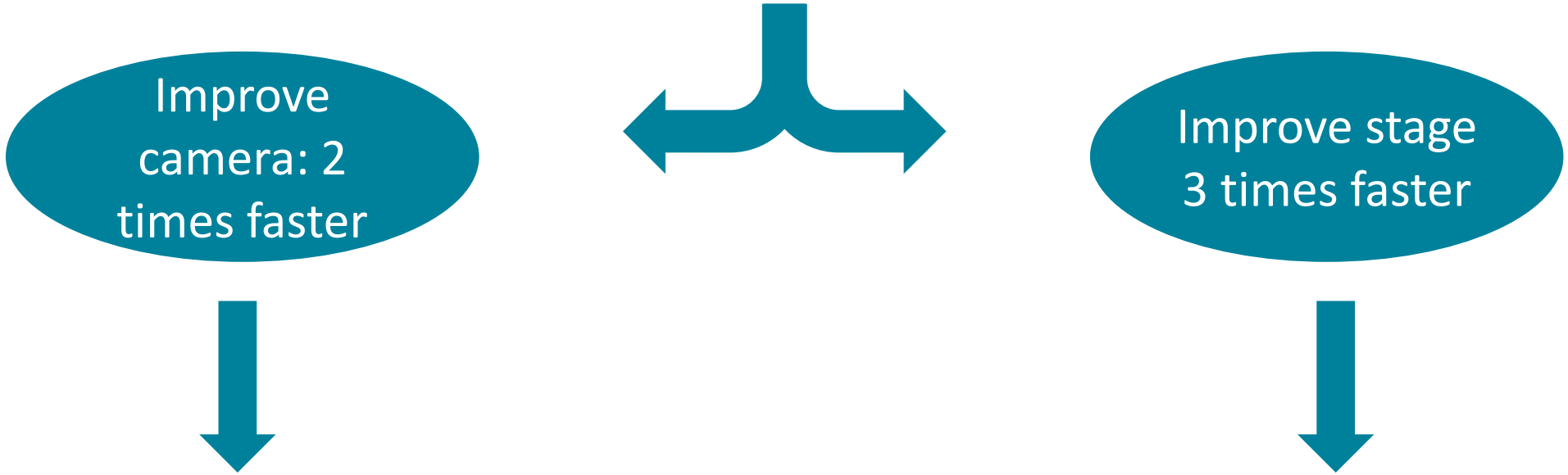
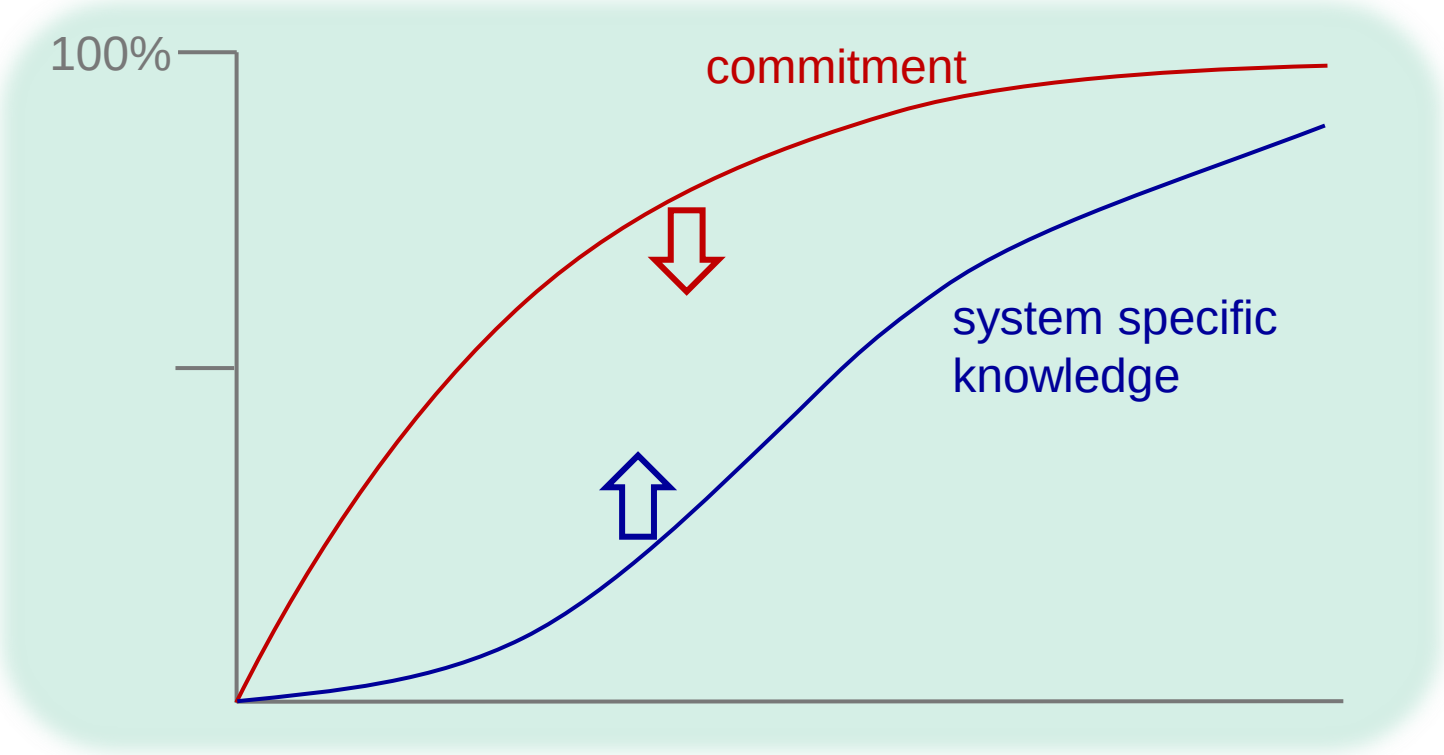
Assumption: innovation costs and other factors are similar



WHY USE MODELS IN SYSTEMS ENGINEERING?



- **Systems engineering aims at narrowing the gap**
- **Modelling i.s.o. building *can* lower the cost commitment**
- **Using models *can* accelerate system knowledge build-up**

MENTI QUESTION 2

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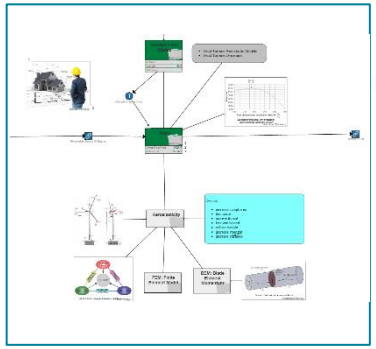
MODEL BASED SYSTEMS ENGINEERING

MBSE

Document-centric
Presentations and
Documents

Model-centric
Multi-user, tool-based,
Connected information



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Systems Engineering using models

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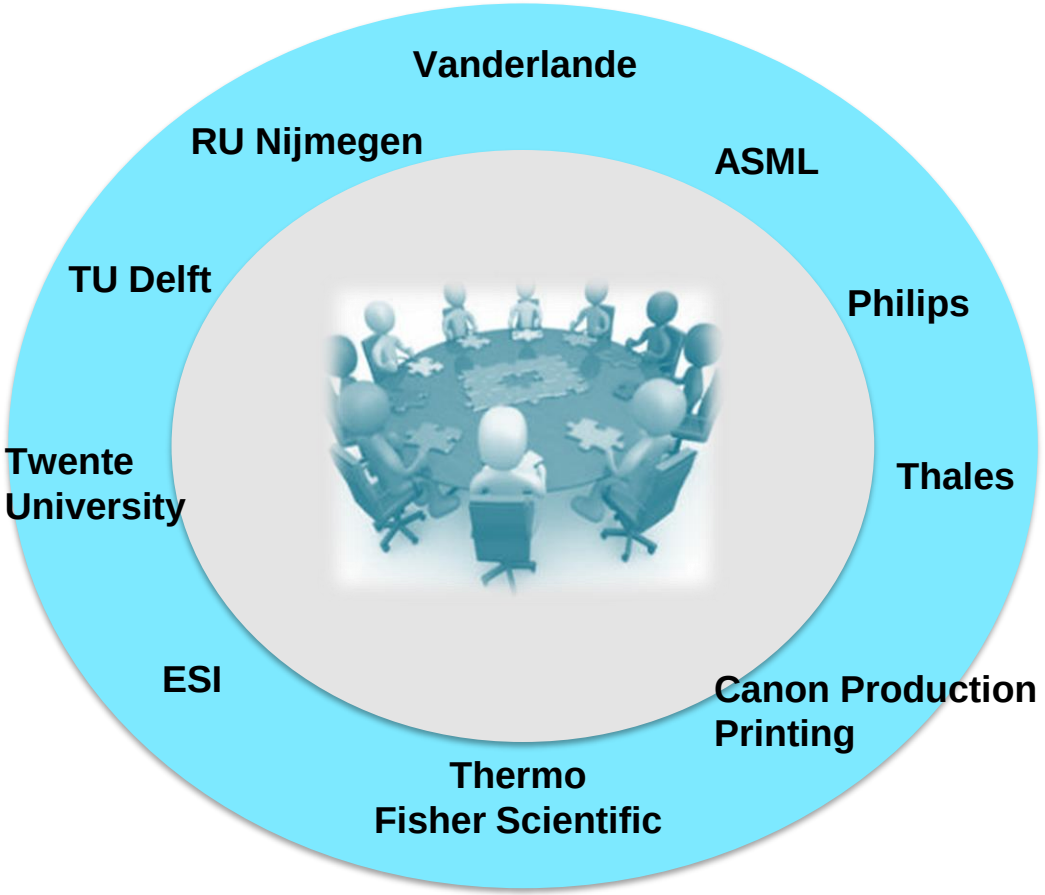
Model Based Systems Engineering

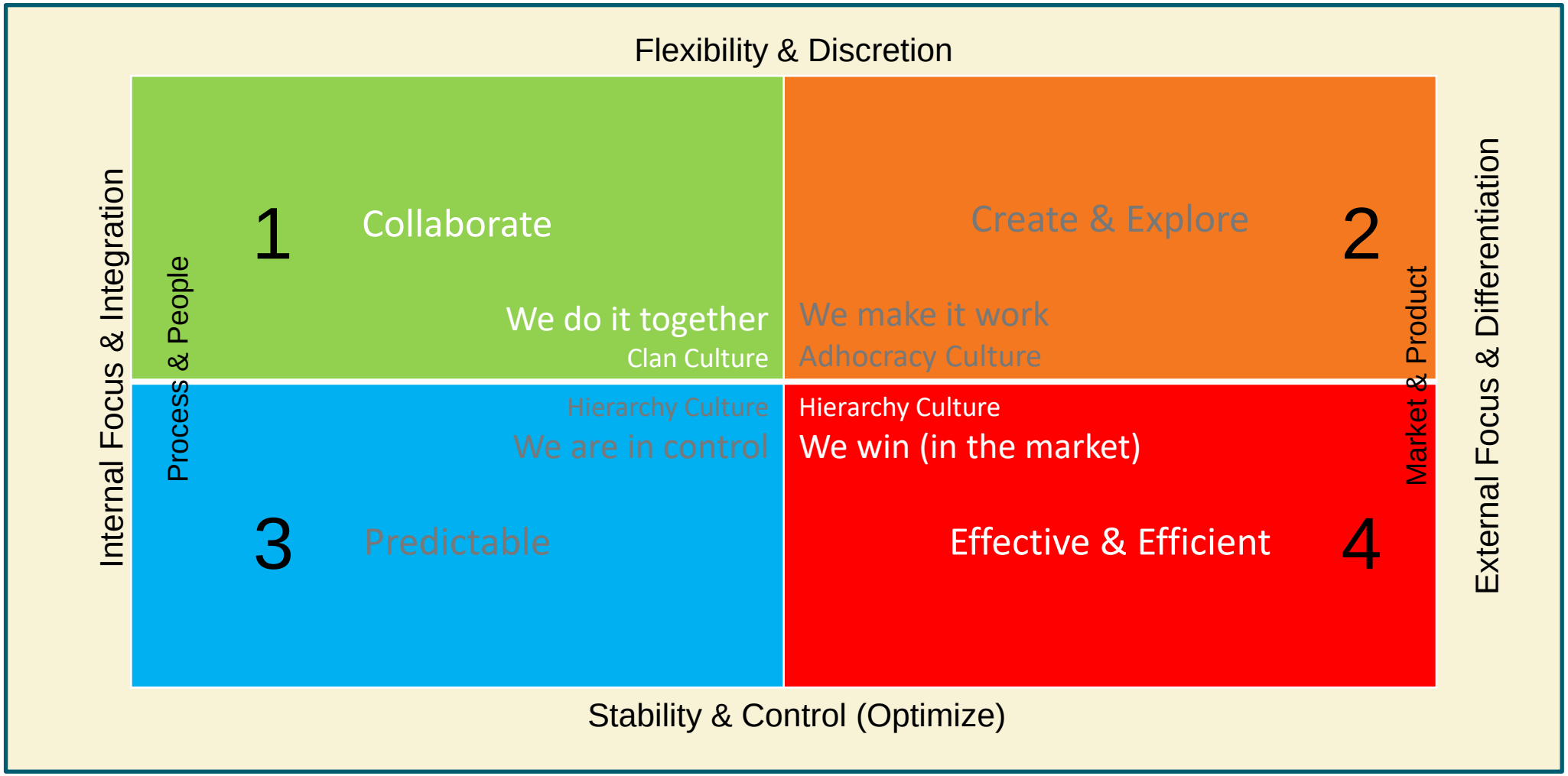
Model Based Systems Engineering:

- **Models are the authoritative, single source of Systems Engineering information for everyone.**
- **Models are not add-ons to documents.**
  Documents (if used at all) are generated from the models.
- **MBSE covers the full System Life Cycle (SLC)**

DEMYSTIFYING MBSE – A STUDY BY ESI AND PARTNERS

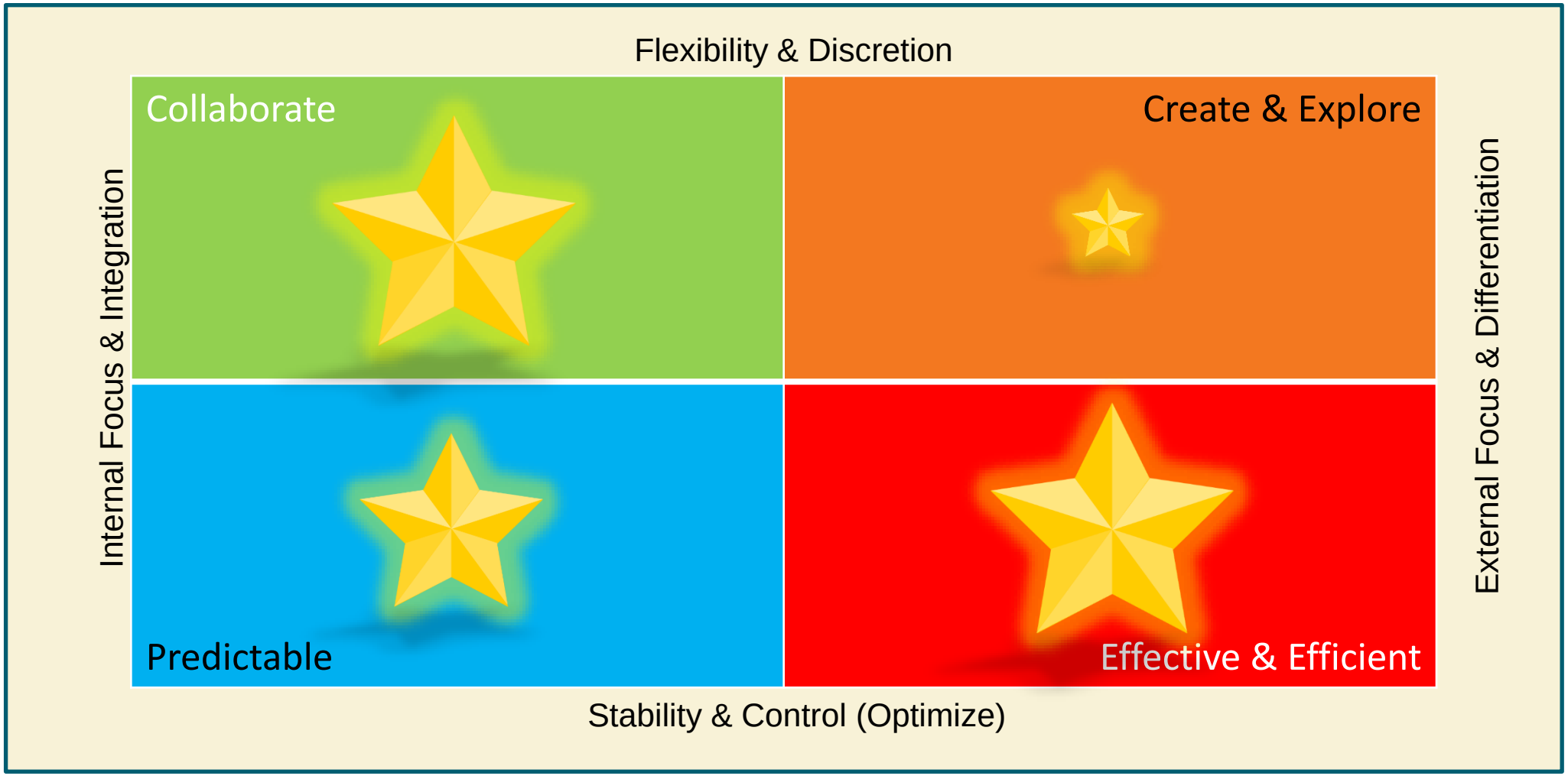


FOUR MOTIVATORS TO INTRODUCE MBSE

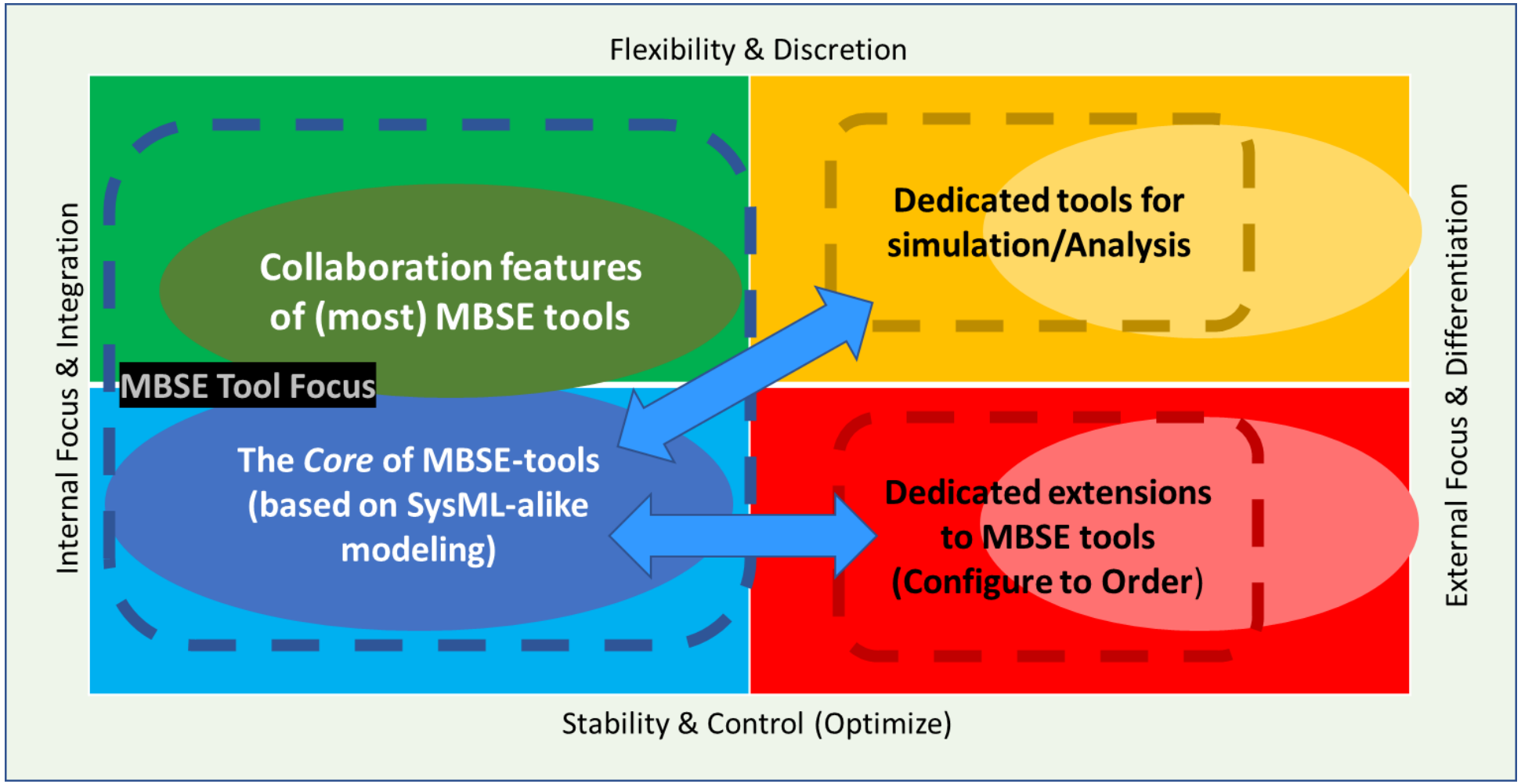


Inspired by Quinn & Cameron and Insights Discovery

WHAT COLOR IS YOUR DRIVER FOR MBSE?



WHAT IS MBSE CORE?



BROWN-FIELD VS GREEN-FIELD

Consistency, Completeness, Cooperation

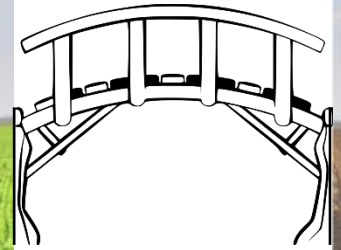
Green Field

Create new designs

Decomposition

Functionality

What MBSE primarily offers



Consistency, Completeness, Cooperation

Brown Field/Evolution/Legacy

Focus on capturing essential knowledge

Integration and Composition (Config to Order)

(also) Emergent Qualities/Non-Functionals

MBSE-needs of High Tech Equipment Industry

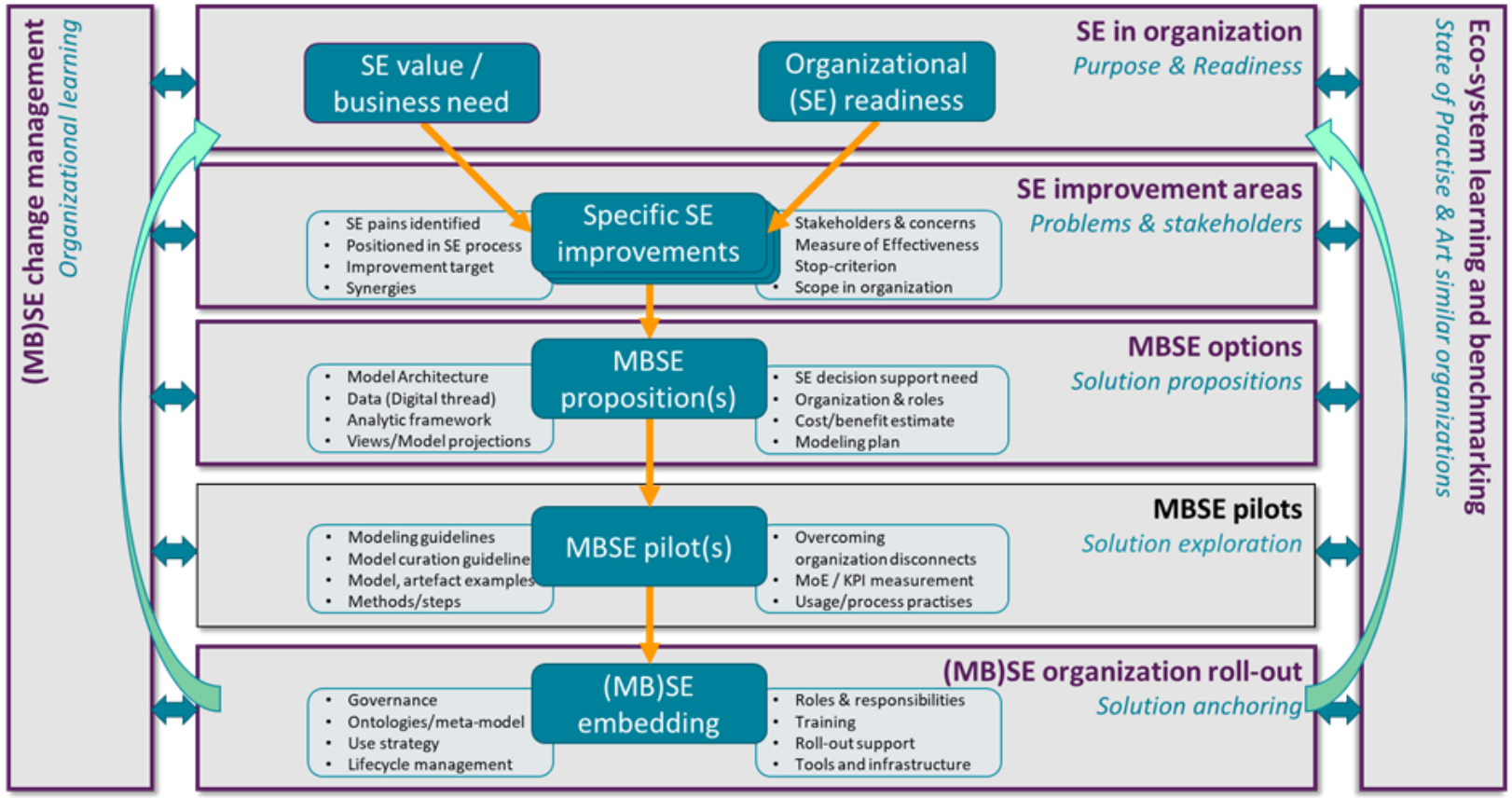
Bridge drawing from https://www.pinclipart.com/
Factory drawing from Old Factory clip art (106417) Free SVG Download / 4 Vector
Tree drawings from: Seasons tree (93431) Free EPS Download / 4 Vector
Autumn trees (93437) Free EPS Download / 4 Vector

CONDITIONS FOR SUCCESSFUL MBSE USAGE IN HIGH TECH EQUIPMENT INDUSTRY

Solutions are needed for MBSE to:

- **pay-off in a brownfield situation (legacy systems)**
- **support platform-based R&D**
- **support managing a large system diversity**
- **multi-disciplinarily model system qualities**
- **combine with agile R&D approaches**

HOW TO INTRODUCE MBSE IN HIGH TECH?
SUBJECT OF PHASE 2 MBSE STUDY 2022-2023



Interested to be involved in this study? Contact us!

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SE EDUCATION IN THE NETHERLANDS

PROJECT: TOWARDS A CONTINUOUS EDUCATION IN SYSTEMS ENGINEERING IN THE NETHERLANDS

Part of pillar 3 of the NxtGen Hightech proposal 'Versterken ecosysteem voor borging blijvende structuurverandering' | 2e tranche Nationaal Groeifonds

Insights:

- **Systems Engineering Competency is a crucial success factor in Dutch industry and business**
- **Education in SE in NL is scattered, not aligned and incomplete**
  - E.g. no Master degree in SE in NL
- **Demand for Systems Engineers is increasing**
- **Generation of experienced Systems Engineers and System Architects is retiring**

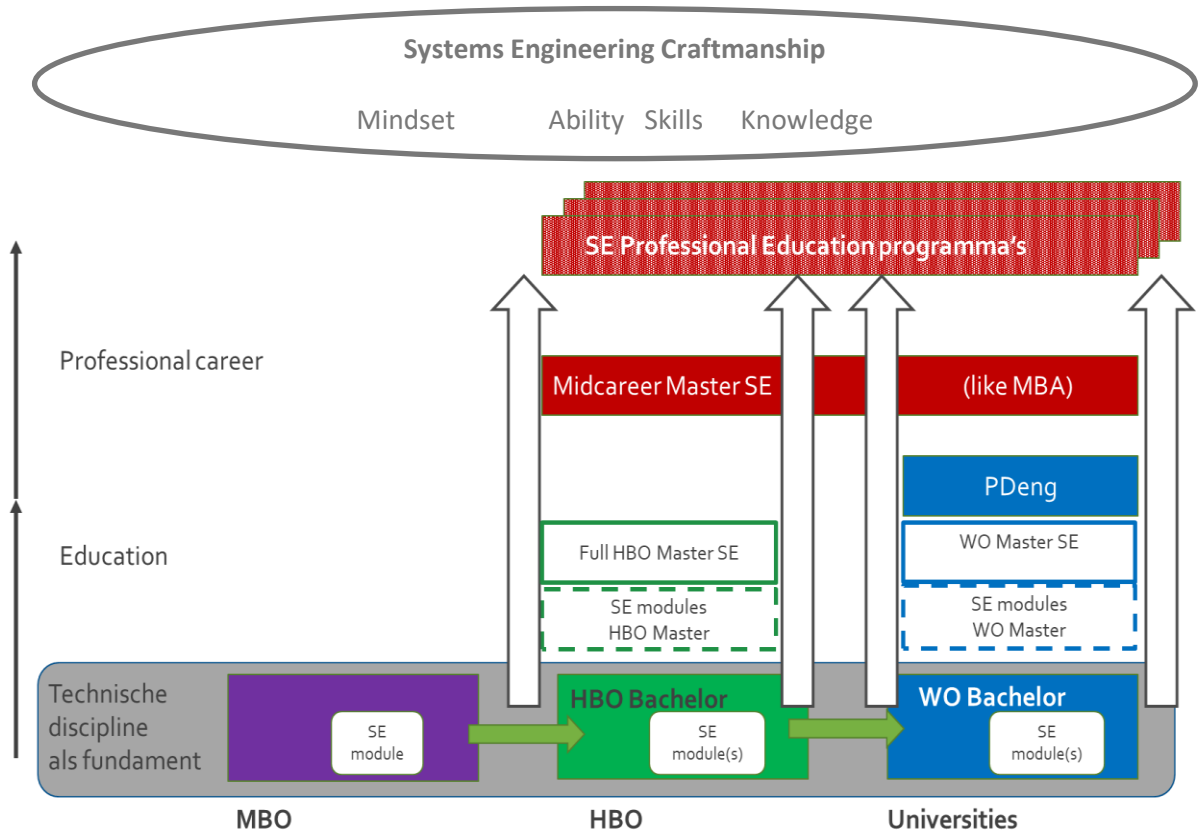
PROJECT: TOWARDS A CONTINUOUS EDUCATION IN SYSTEMS ENGINEERING IN THE NETHERLANDS

Part of pillar 3 of the NxtGen Hightech proposal 'Versterken ecosysteem voor borging blijvende structuurverandering' | 2e tranche Nationaal Groeifonds

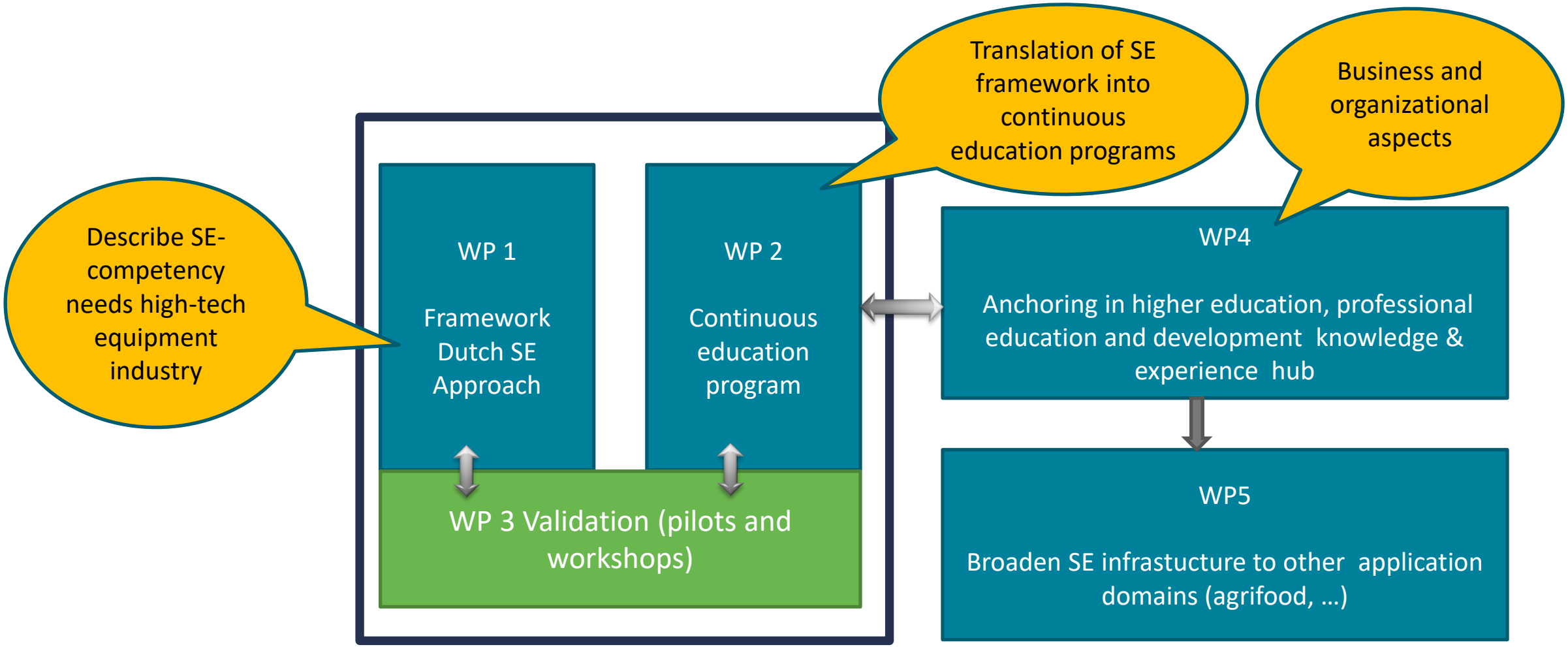
- **Building on Brainport SE study, a core team of stakeholders initiated this project proposal**
- **All major high tech equipment industries have offered in-kind support**
- **5 Mln€ subsidy from National Groeifonds**
- **Runtime 7 years**
- **Start: Q1 2023**

PROJECT GOALS

- Realize a continuous education program at Bachelor and Master level, and life-long Professional Education.
- Target groups: all engineers, from students **with SE potential to experienced s**enior Systems Engineers in industry.
- Sub-objectives:
  - Define an explicit SE framework, based on the current successful way of doing SE in Dutch high-tech equipment industry.
  - Realize a Dutch Systems Engineering knowledge and experience hub where education, research, and development meet and is being consolidated.
  - Define a desired Professional Education Portfolio.



PROJECT STRUCTURE – 2023-2030



SUMMARY

1. **Engineering:** ***Dutch High Tech***
2. **Systems Engineering:** ***In The Netherlands***
3. **Based Systems Engineering:** ***Methodology innovation***
4. **Model Based Systems Engineering:** ***Value for Dutch High Tech***
5. **SE education in The Netherlands:** ***National Growthfund project***

THANK YOU

Q&A