

Mastering Systems Integration all slides

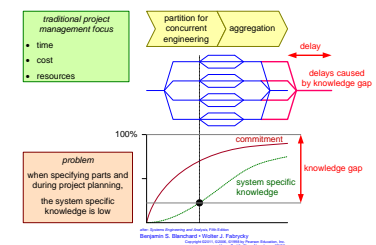
by *Gerrit Muller*
TNO-ESI, USN-SE

Abstract

The course Mastering Systems Integration discusses multiple perspectives on systems integration. The dominating principle underlying the course is that unknowns and major uncertainties need to be found as early as possible to mitigate system and project consequences. A good subtitle of the course is "Architects meet Project Leaders meet Reality."

The complete course TM is owned by TNO-ESI. To teach this course a license from TNO-ESI is required. This material is preliminary course material.

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status: concept
version: 1.0



Mastering Systems Integration; Introduction

by *Gerrit Muller* TNO-ESI, University College of South-Eastern Norway

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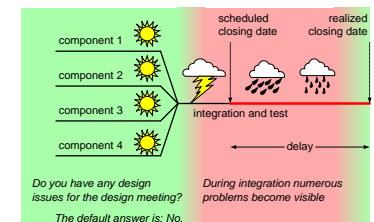
Abstract

This presentation introduces the ideas behind the course Mastering Systems Integration. Systems integration requires cooperation from many project members, such as project leader, product manager, architect, lead designer, integrator, and tester. Integration is more than a simple aggregation as the reverse of the decomposition. The purpose of systems integration is to detect anything nasty that has not been foreseen as early as possible.

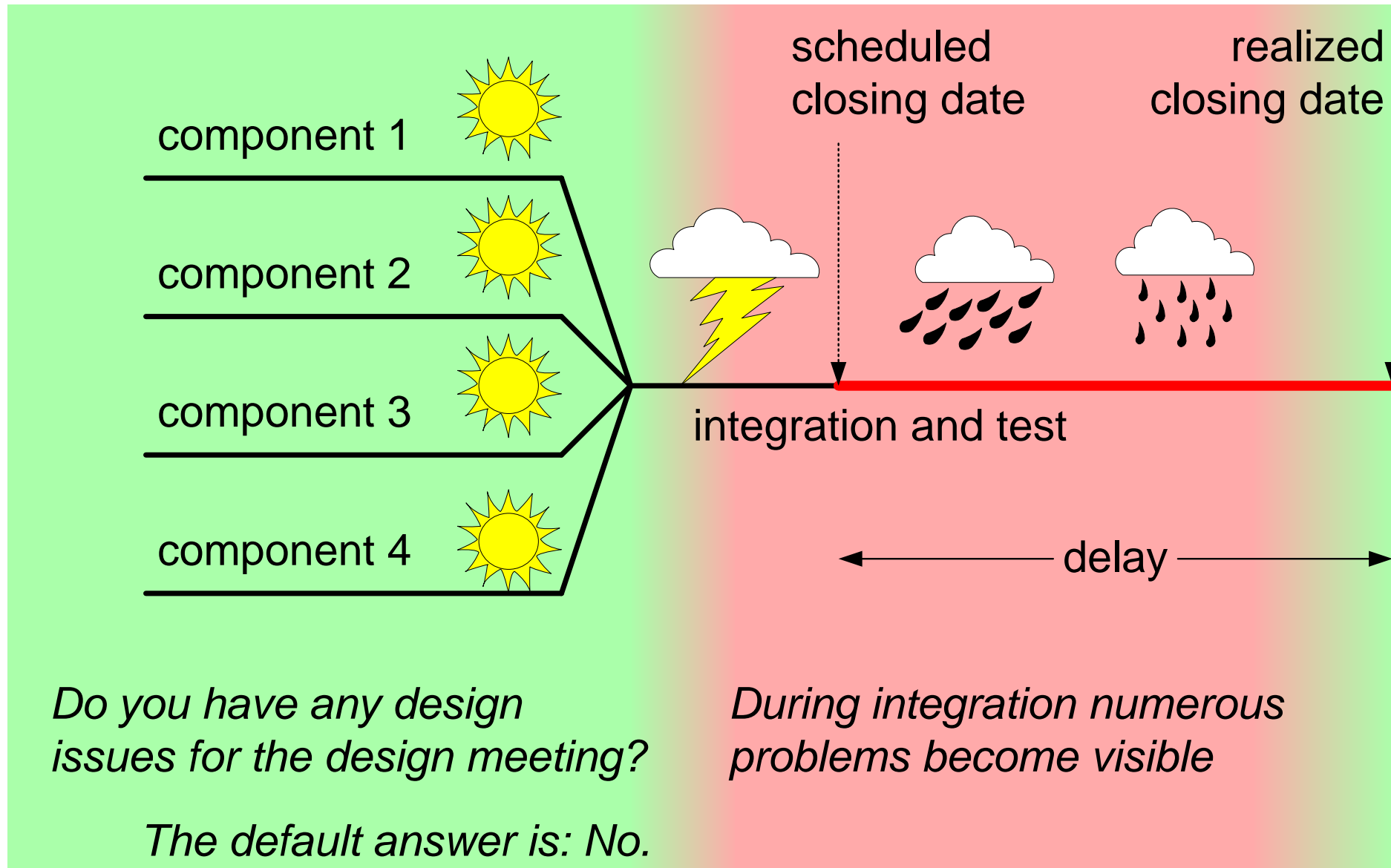
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draft
version: 0.5



Integration uncovers hidden problems



Project Team; Contributions to Integration

Operational

Project Leader

- *planning*
- *organizing*
- *resources*
- *progress*

Technical

Architect Lead Designer Integrator

- *key functionality*
- *key performance parameters*
- *concept selection*
- *system design*
- *integration sequence*

Tester

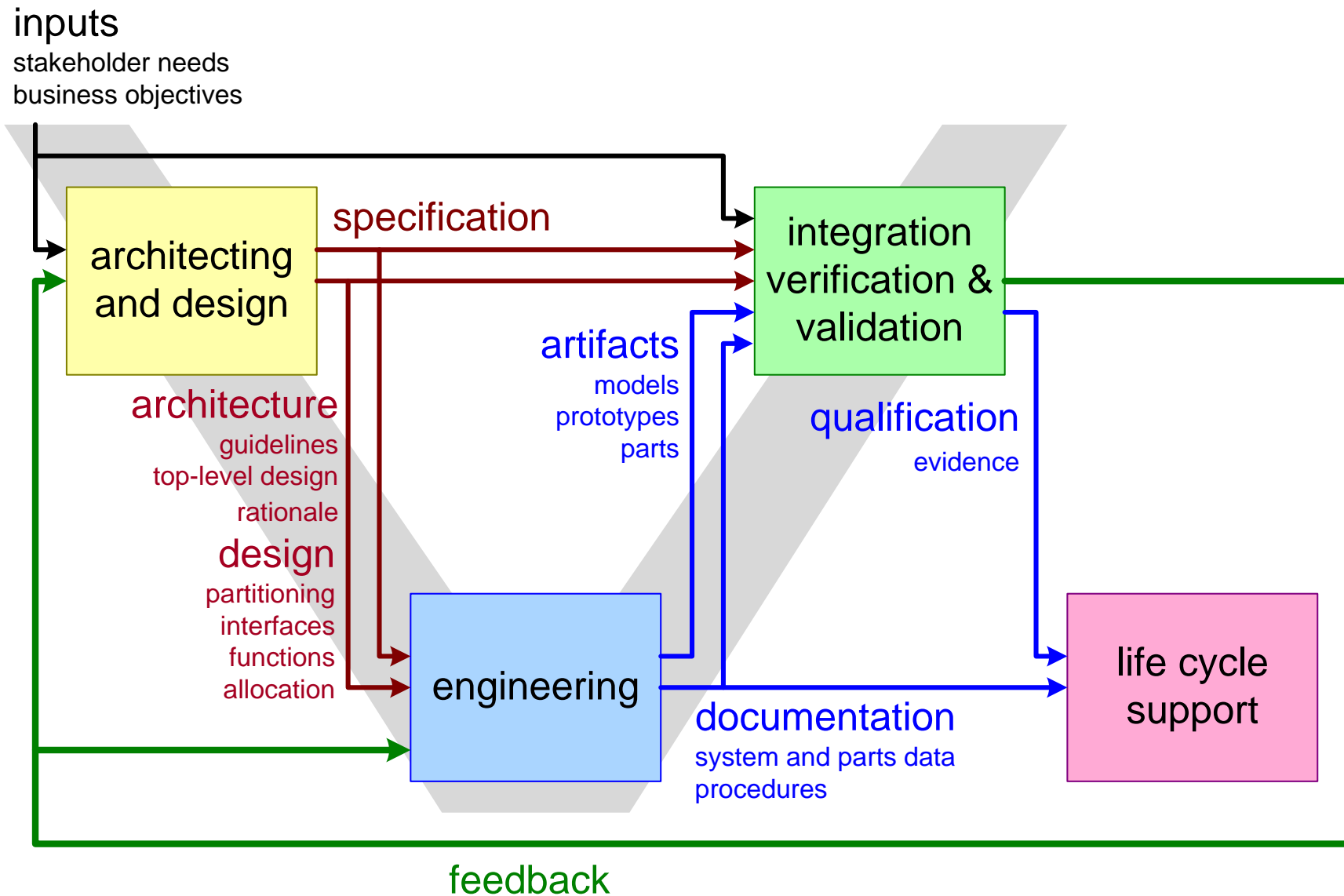
- *testing*
- *test configuration*
- *testware*
- *test specifications*
- *test reports*

Commercial

Product Manager

- *customer needs*
- *customer value*
- *system specification*

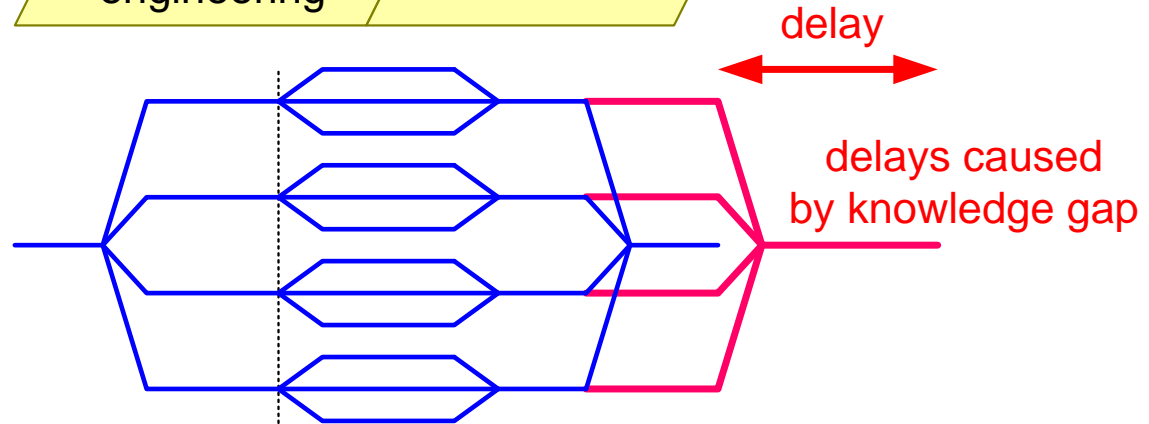
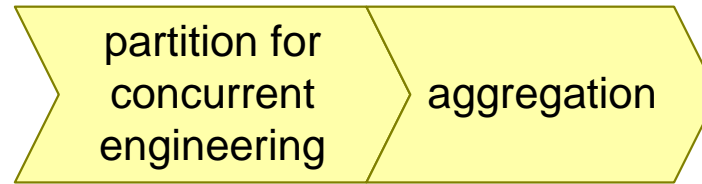
The Role of Integration in Development



The Pain of Systems Integration

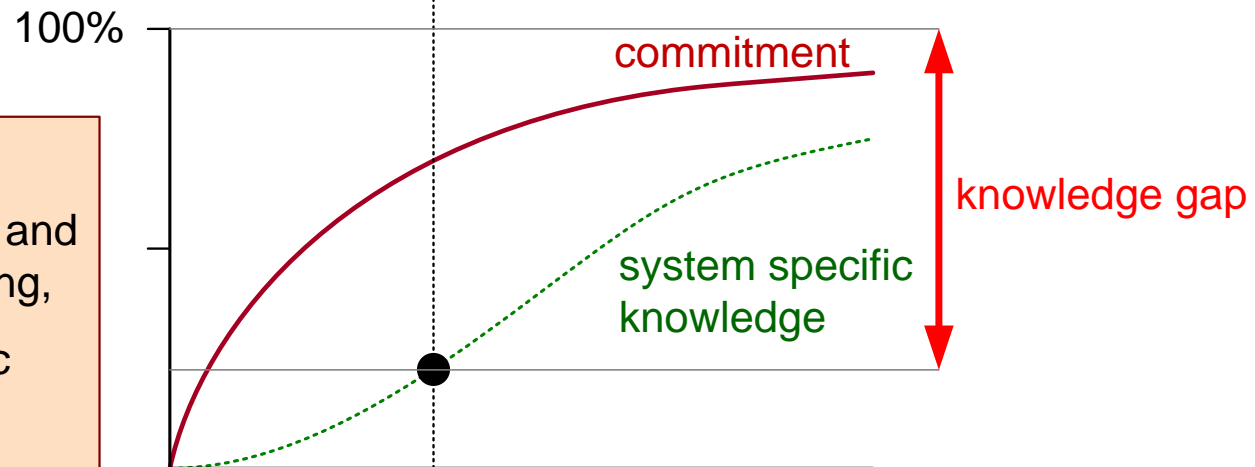
traditional project management focus

- time
- cost
- resources



problem

when specifying parts and during project planning, the system specific knowledge is low



after: *Systems Engineering and Analysis*, Fifth Edition
 Benjamin S. Blanchard • Wolter J. Fabrycky
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 Upper Saddle River, New Jersey 07458

Systems Integration Approach

Systems Integration starts when the project starts

The Integration perspective **drives** the project schedule by addressing the **major risks** from

volatility, uncertainty, complexity and **ambiguity**

Systems Integration strives to **Fail Early**; it is an early verification and validation

Systems Integration requires **multidisciplinary teamwork**, e.g.

Integrators, Testers, Architects, Designers, Engineers, Project Leaders, Product Managers, and others

Systems Integration complements Systems Architecting

Mastering Systems Integration; Course Overview

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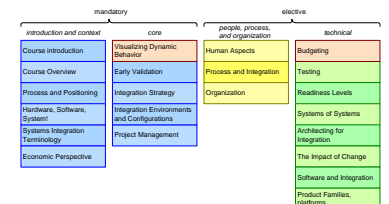
Abstract

Course overview of the course Systems Integration.

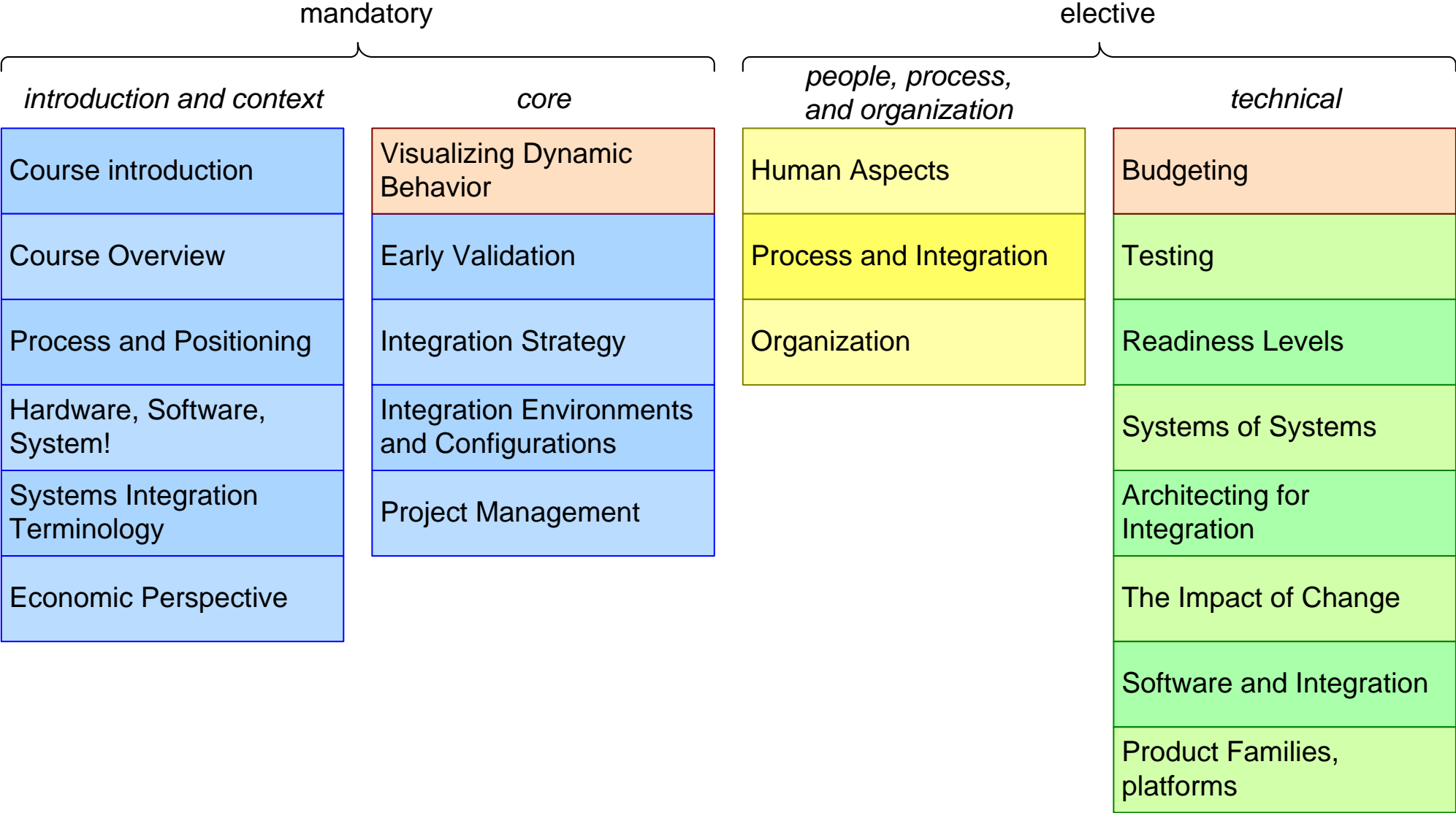
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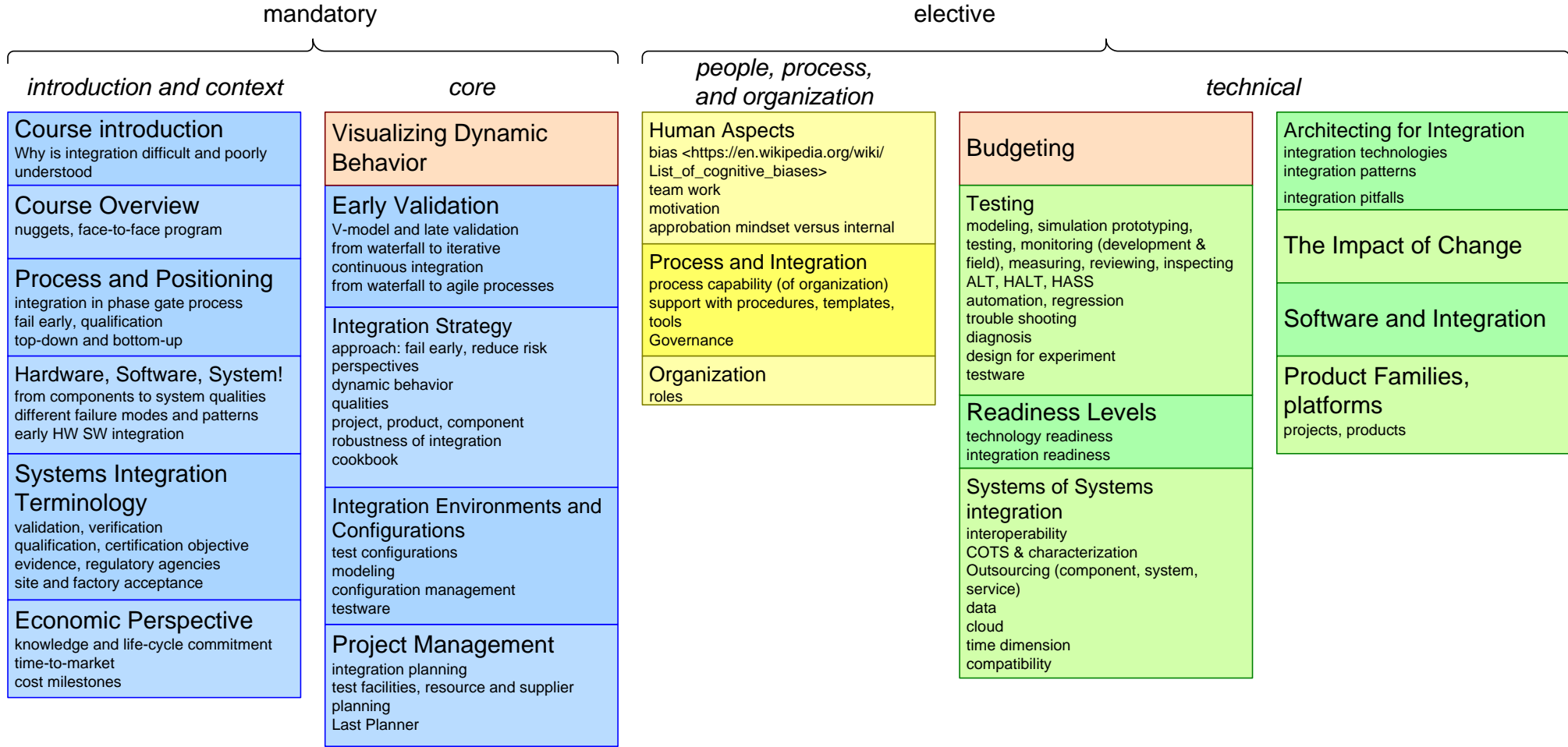
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status: draft
version: 0.5



Nuggets Course Mastering Systems Integration



Content per Nugget



Assignments in Face-to-Face Module

System Specification

- determine **KPPs** and their quantified specification
- assess **risk** of KPPs caused by volatility, uncertainty, complexity and ambiguity
pick one **high-risk** KPP to elaborate
- describe **typical use** (including circumstances in the **context**) related to KPP

System design

- make system, SW, and HW **block diagrams** (parts, interfaces, connections)
- model **dynamic behavior** resulting in the KPP
- map **dynamic behavior** on **block diagrams** and **budget**: quantify contributions to KPP
- re-assess **risks** of KPP

Reflection and Evaluation

- identify **tensions** or **gaps** in processes, organization, people, tools, instrumentation, context knowledge, etc. for executing the integration.

Systems Integration Plan

- determine an incremental **integration sequence** to measure the KPP as early as possible
- assess for the parts contributing to the KPP
 - **fitness for purpose** in customer context
 - **integration configurations** and **testware**
 - **supplier** and **logistics** status
 - **technology readiness**
 - **development** and **resource** status
- Identify **tensions** with development, logistics status, and availability of testware
and transform the sequence in a **(PERT) plan** with required resources and **integration configurations**
- assess **robustness** of the plan
- capture results in presentation

3-Day Face-to-Face Schedule

	day 1	day 2	day 3
9:00	course intro	early validation	integration strategy
10:00	systems integration intro	make system, SW, and HW block diagrams (parts, interfaces, connections)	determine an incremental integration sequence to measure the KPP ASAP
11:00	case discussion	dynamic behavior	project management
12:00	systems integration context	model dynamic behavior resulting in the KPP	assess integration configurations and testware, supplier and logistics status, technology readiness ,
13:00	determine KPPs and their quantified specification	lunch	lunch
14:00	lunch	reflection and discussion	and development and resource status
15:00	reflection and discussion	budgeting	reflection and discussion
16:00	assess risk of KPPs caused by volatility, uncertainty, complexity and ambiguity	map dynamic behavior on block diagrams and budget . quantify contributions to KPP	identify tensions and transform sequence into a (PERT) plan
17:00	describe typical use (including circumstances in the context) related to KPP	re-assess risks of KPP	present, discuss, reflection and discussion
	reflection and discussion	reflection and discussion	

4-Day Face-to-Face Schedule

	day 1	day 2	day 3	day 4
9:00	course intro	early validation	project management	elective
10:00	systems integration intro	make system, SW, and HW block diagrams (parts, interfaces, connections)	re-assess risks of KPP	identify tensions and transform sequence into a (PERT) plan
11:00	case discussion	dynamic behavior	determine an incremental integration sequence to measure the KPP ASAP	elective
12:00	systems integration context	model dynamic behavior resulting in the KPP	readiness levels, systems of systems, elective	reflection and discussion
	determine KPPs and their quantified specification		reflection and discussion	
13:00	lunch	lunch	lunch	lunch
14:00	reflection and discussion	reflection and discussion		elective
15:00	assess risk of KPPs caused by volatility, uncertainty, complexity and ambiguity	integration strategy environments and configurations	assess integration configurations and testware, supplier and logistics status, technology readiness , and development and resource status	assess robustness of plan
16:00	describe typical use (including circumstances in the context) related to KPP	map dynamic behavior on block diagrams and budget : quantify contributions to KPP		make and give presentation to management
17:00	reflection and discussion	elective	elective	reflection and discussion

<i>people, process, and organization</i> <ul style="list-style-type: none"> human aspects process and integration organization 	<i>technical</i> <ul style="list-style-type: none"> budgeting testing systems of systems 	<ul style="list-style-type: none"> architecting for integration impact of change software and integration product families, platforms
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electives

Project Overview How To

by *Gerrit Muller* USN-SE

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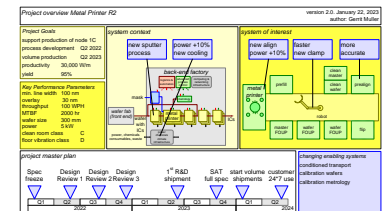
Abstract

A project overview shows the overview of a project on a single slide or sheet. The overview helps the team to share the same understanding of scope, objectives, and timeline.

Distribution

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version: 0.2



Project Overview Canvas

<i>Project Title</i>		meta information, e.g. version, date author, owner
<i>Project Goals</i> <ul style="list-style-type: none">• specific and quantified	<i>system context</i> <ul style="list-style-type: none">• visualization (drawing, block diagram, 3D model, or photo) of the system context• indication of changes in the context	<i>system of interest</i> <ul style="list-style-type: none">• visualization (drawing, block diagram, 3D model, or photo) of the system• indication of changes in the system of interest
<i>Key Performance Parameters</i> <ul style="list-style-type: none">• specific and quantified		
<i>project master plan with timeline</i> <ul style="list-style-type: none">• timeline with 5 to 10 milestones, especially deliverables• specific and quantified		<i>optional information, e.g.</i> <ul style="list-style-type: none">• enabling systems• stakeholders• external or internal interfaces• constraints, e.g. applicable legislation

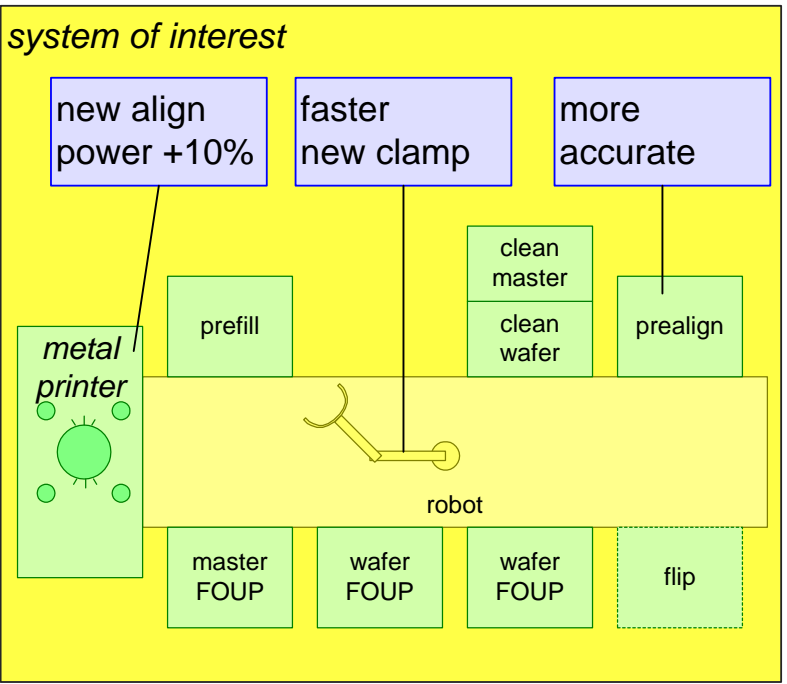
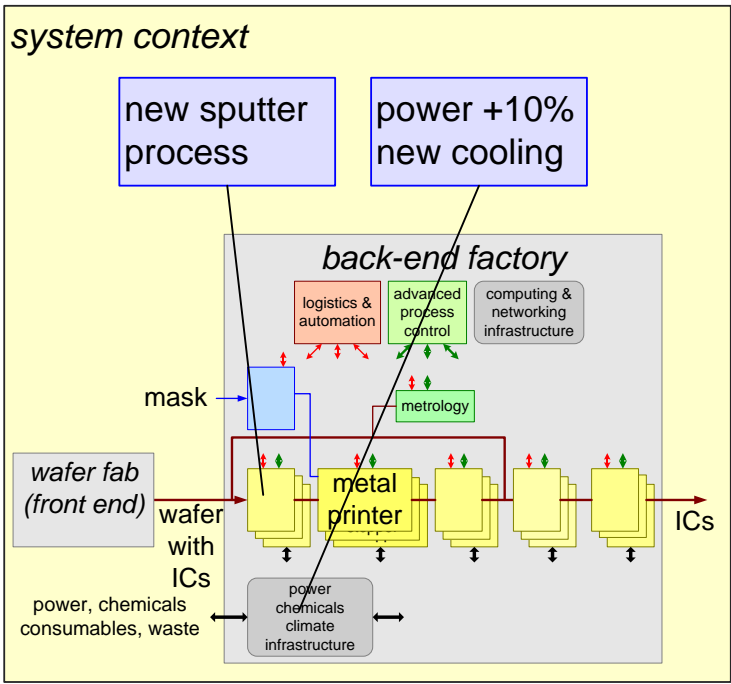
Example Project Overview

Project overview Metal Printer R2

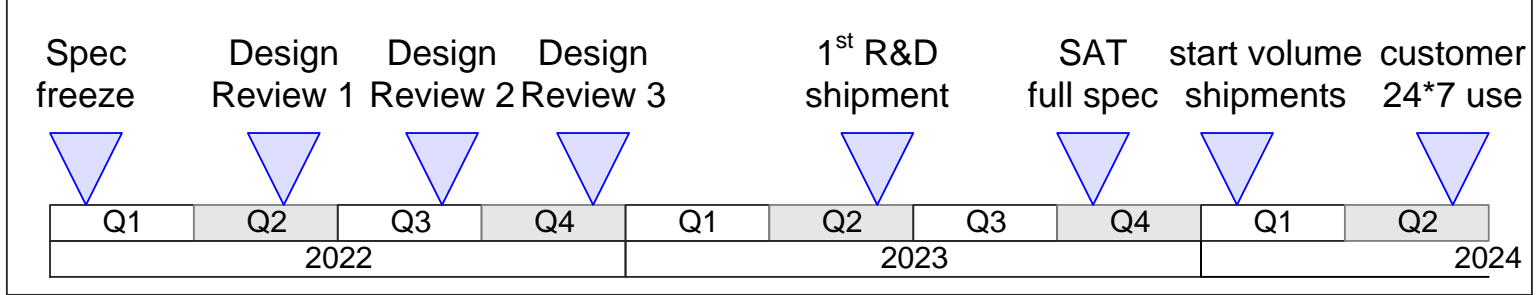
version 2.0. January 22, 2023
author: Gerrit Muller

Project Goals
 support production of node 1C
 process development Q2 2022
 volume production Q2 2023
 productivity 30,000 W/m
 yield 95%

Key Performance Parameters
 min. line width 100 nm
 overlay 30 nm
 throughput 100 WPH
 MTBF 2000 hr
 wafer size 300 mm
 power 5 kW
 clean room class C
 floor vibration class D



project master plan



changing enabling systems
 conditioned transport
 calibration wafers
 calibration metrology

Project Overview Canvas

<i>Project Title</i>	meta information, e.g. version, date author, owner
<i>Work Breakdown Structure</i> <ul style="list-style-type: none">• visualization• <i>builds upon the Product Breakdown Structure</i>	<i>Project Master Plan</i> <ul style="list-style-type: none">• PERT plan with major milestones <i>project organization</i> <ul style="list-style-type: none">• allocation of roles• specific additions or deviations

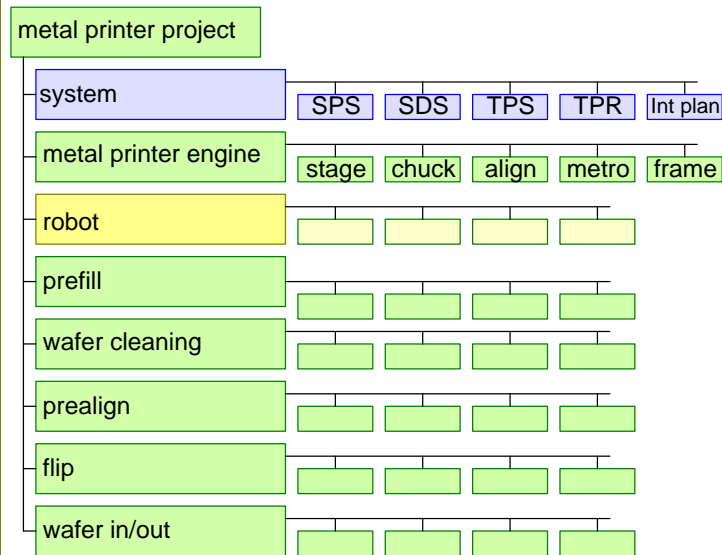
Example Project Overview

Metal Printer

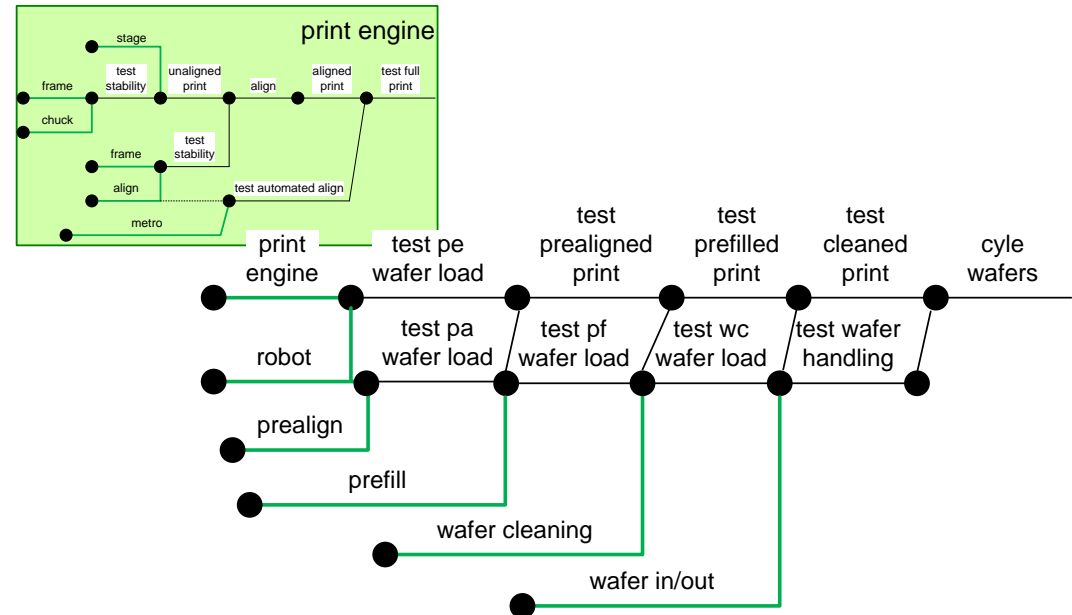
version 0.1, 2023-02-11

author: Gerrit Muller

Work Breakdown Structure



Project Master Plan



project organization

Project Leader: P.L. Eader

Product Manager: P.M. Anager

Architect: Archie Tect

Mastering Systems Integration; Assignments

by *Gerrit Muller* TNO-ESI, USN-SE

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Abstract

All assignments of the course Mastering Systems Integration.

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logo

TBD

Pre-assignment

Make an initial project overview for your own project

Project Title

meta information, e.g. version, date, author, owner

Project Goals

- 3 to 5 specific and quantified objectives

system context

- sketch the next generation system context, e.g. a drawing, block diagram, 3D model, photo of the system context
- indicate changes in the context compared to the current generation system

system of interest

- sketch your next generation system, e.g. drawing, block diagram, 3D model, photo
- indicate changes compared to the current generation system

Key Performance Parameters

- 5 to 10 specific and quantified requirements

project master plan with timeline

- time line with 5 to 10 milestones, especially deliverables. specific and quantified
- first light, prototype shipment, 1st SAT @OEM, 1st SAT @OEM's customer, start volume production

other relevant project information

- enabling systems
- stakeholders
- external or internal interfaces
- constraints, e.g. applicable legislation

Sketch the system-of-interest

What are the most relevant project goals?

Sketch the project master plan (the main milestones and their timing)

Determine 5 to 10 **Key Performance Parameters** (KPP) of the System

Quantify these KPPs

Define the KPPs roughly, using a **Use Case**

VUCA Causes Risks

VUCA =

Volatility

Uncertainty

Complexity

Ambiguity

Assess the risk for each KPP

Explain why this KPP may suffer from this risk

Select one KPP to work on in the remainder of the Face-to-Face workshop

this KPP should be “hot” (lot of organizational buzz)

you may also select two “conflicting” KPPs

Define the typical use (by customer stakeholders) of the system in relation to the selected KPP.

This use case helps to define the KPP further

This use case will guide the verification and validation

Make Block Diagrams

Make block diagrams of the system, the software, and the hardware.

Block diagrams show parts, and interfaces or connections.

These block diagrams need tens of blocks.

Model the Dynamic Behavior of the System.

Focus on the Dynamic Behavior that relates to the KPP.

Visualize the Dynamic Behavior with various sketches, diagrams, or graphs (see Visualizing Dynamic Behavior for inspiration).

Map the Dynamic Behavior on the block diagrams.

Transform this into a budget:

Quantify contributions of parts and functions to the KPP.

Re-assess the risks for the chosen KPP

using the insights gained so far

These risks are leading when defining the integration sequence

Determine an Incremental Integration Sequence

Determine an incremental ***integration sequence*** to build confidence in the KPP ASAP.

Strive for about 6 main increments.

Reason starting at the end result and then backward in time.

For each increment determine its prerequisites in terms of parts, interfaces, functions, and performance levels.

assess the planning from the perspectives:

- ***fitness for purpose*** in customer context
- ***integration configurations*** and ***testware***
- ***supplier*** and ***logistics*** status
- ***technology readiness***
- ***development*** and ***resource*** status

Transform the integration sequence and the planning from the other perspectives into a **PERT-plan**.

A PERT-plan focuses on **activities** and their mutual **relations**; the logic of the plan. Time and resources are secondary information.

Assess how well the PERT plan addresses the original risks in the KPPs.

Assess the robustness of the PERT-plan for changes.

All assumptions in the integration plan will probably change. A good integration PERT-plan shouldn't change much.

Prepare Final Presentation

Prepare a presentation for the management

- to communicate the systems integration approach
- its rationale
- and its impact on the project, the test configurations, the schedule, the organization, and the suppliers

Add a slide on the course learnings and reflections

Content for Final Presentation

- Goal of this presentation, main message, desired outcome
- Mission/goal of end customer
- Master plan, milestones and dates
- Key performance parameters of the system
- Block diagrams (20..30 blocks), dynamic behavior (20..30 blocks), some supporting visualizations, budget
- Integration strategy and sequence
- PERT plan (proposal)
- Summary and specific actions, and recommendations (e.g. allocate these resources, order ..., etc.)

Add a slide on the course learnings and reflections

Homework Project

A4 Project/System Overview

A4 Master plan with time lines

Project description

- Architecture overview (enabling systems, context, SOI, partitioning, interfaces, dynamic behavior, KPP's, MOEs, critical Design and Technology choices) + Rationale
- Risk Analysis + Rationale
- Ideal integration sequence PERT plan + Rationale
- Project plan inputs (resources, suppliers, customers, technologies, test mgmt...) + Rationale
- Project plan + Rationale

Evaluation of the project description (how mature, how accurate, where are gaps?)

Reflection report

Mastering Systems Integration; Process and Positioning

by *Gerrit Muller* [TNO-ESI, University of South-Eastern Norway]

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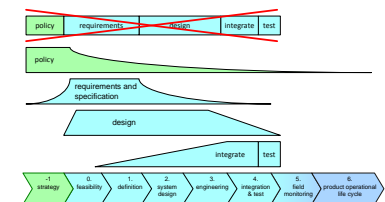
Abstract

This lesson positions systems integration as process in the development processes.

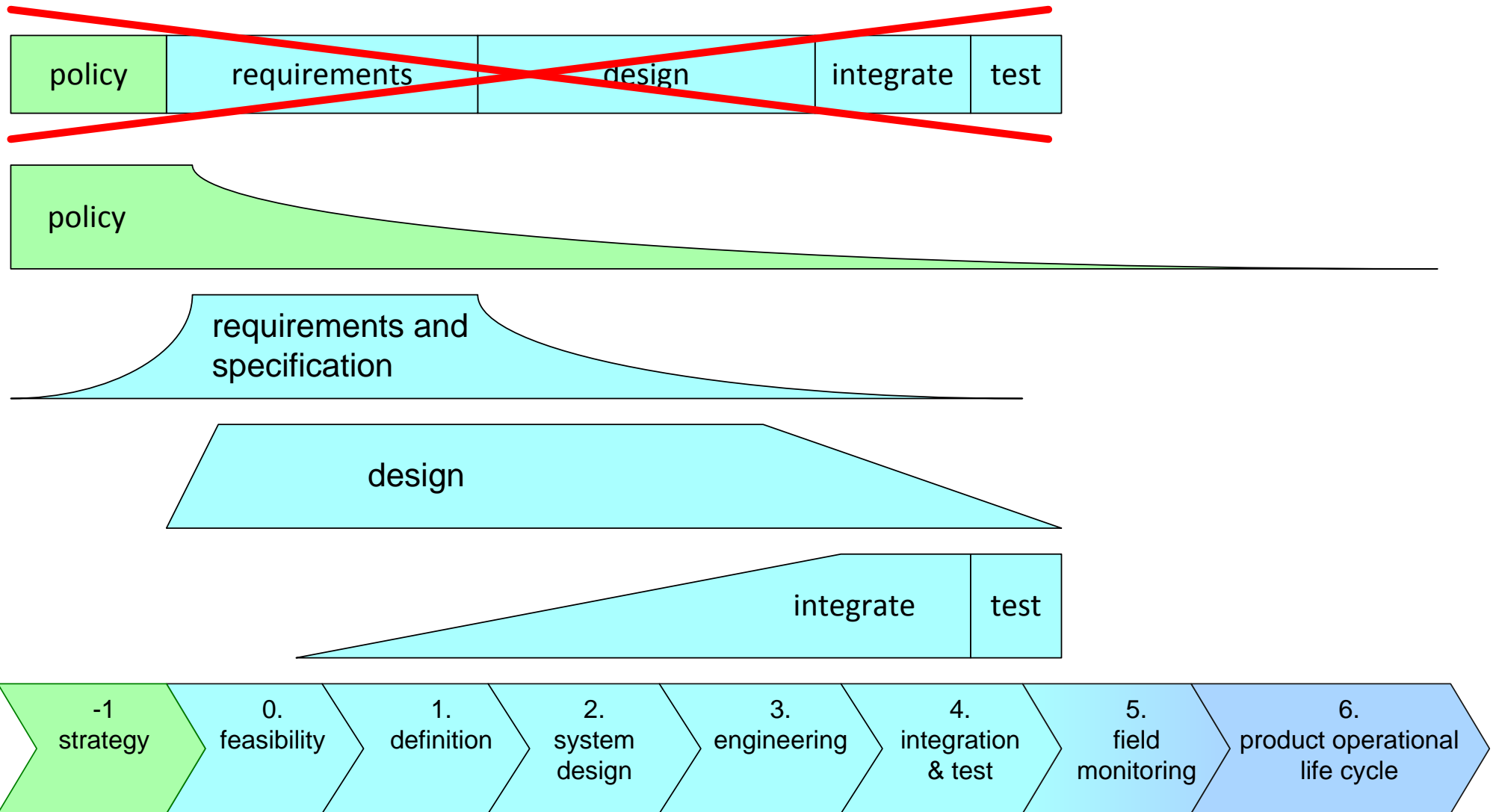
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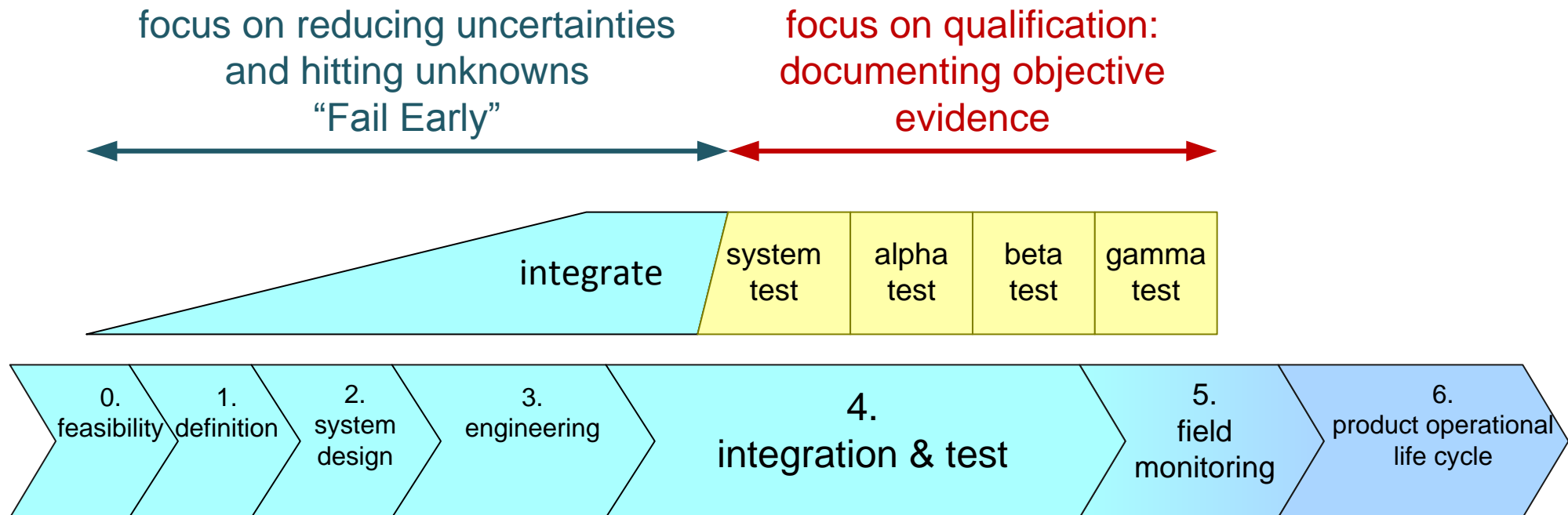
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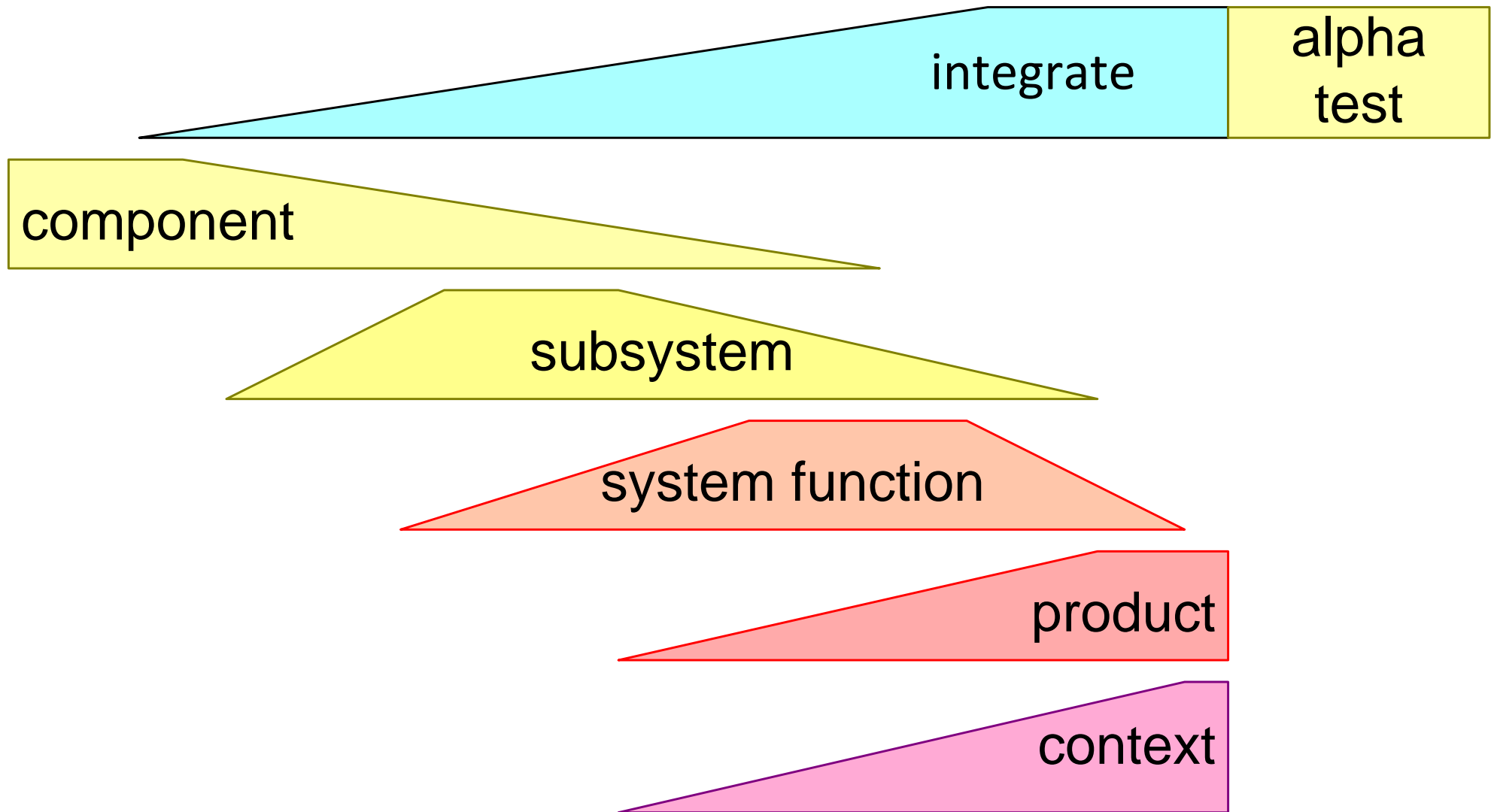
Typical Concurrent Product Creation Process



Zooming in on Integration and Tests



Integration Takes Place in a Bottom-up Fashion



Mastering Systems Integration; Hardware, Software, Systems!

by *Gerrit Muller* TNO-ESI, University of South-Eastern Norway]

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Abstract

Hardware and software differ in their characteristics, which impacts their role in systems integration. The main message in this lesson is that the focus of integration is at the system, where both hardware and software contribute.

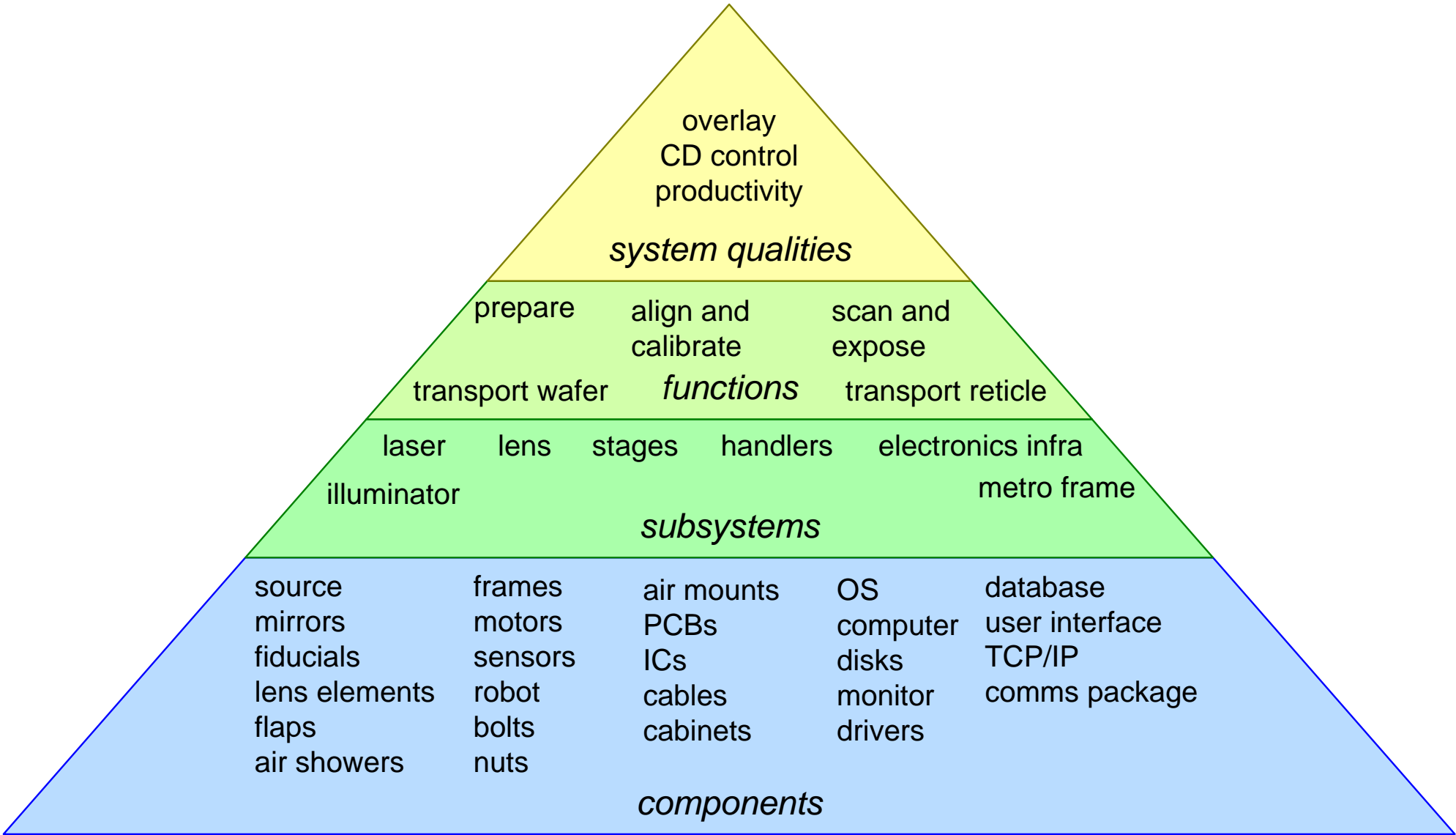
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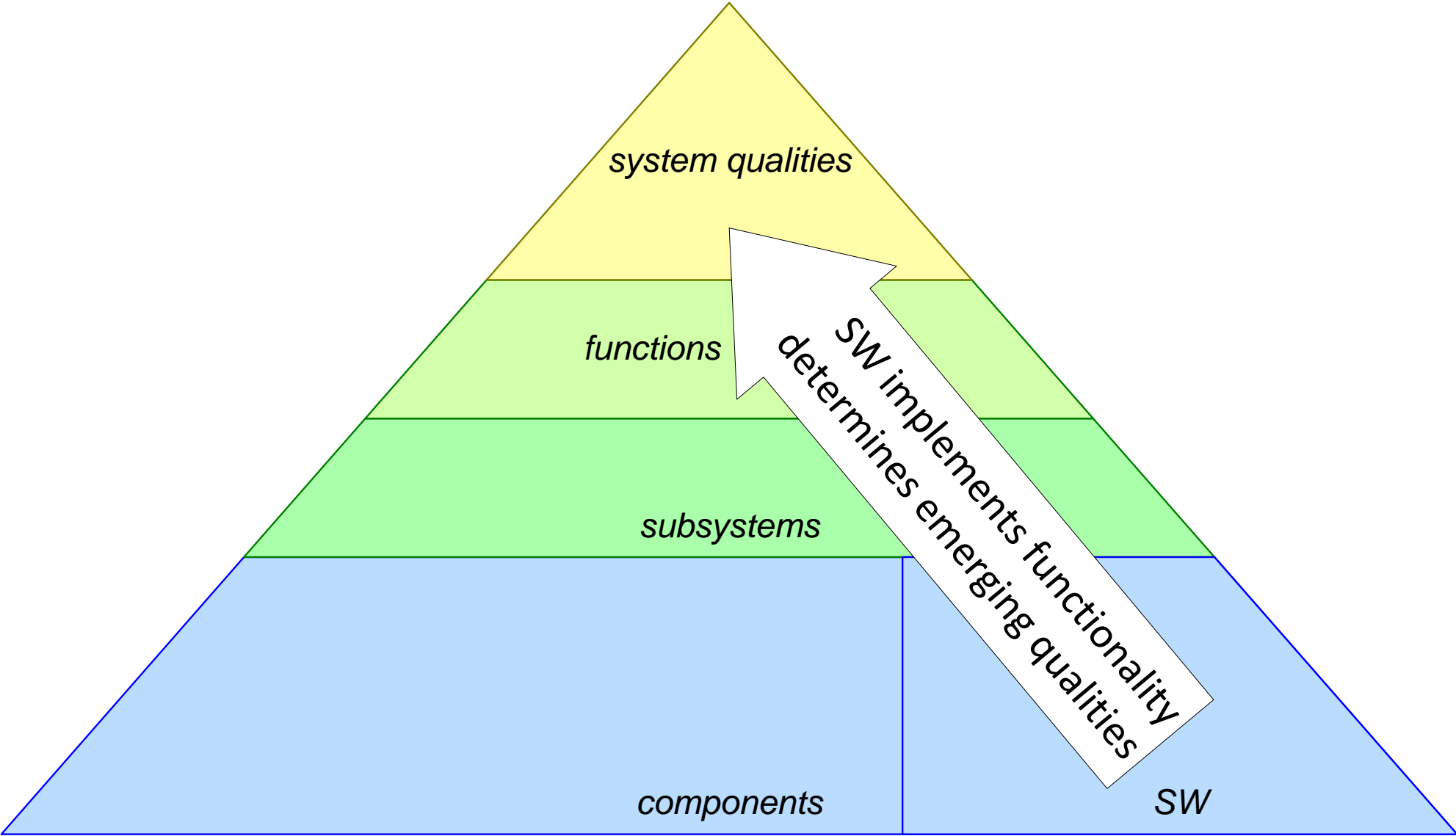
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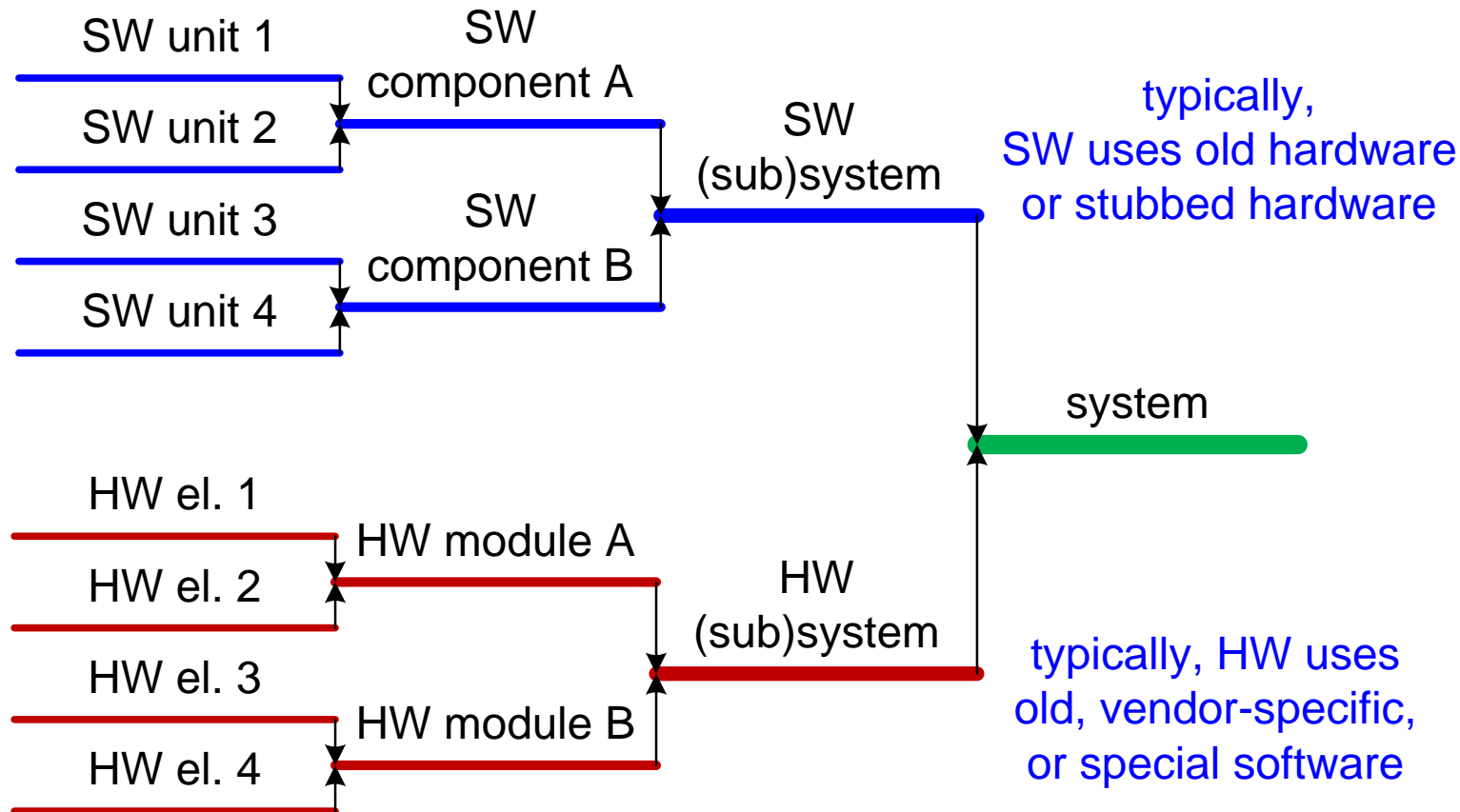
From Components to System Qualities



Role of Software



Pitfall: Late HW-SW Integration



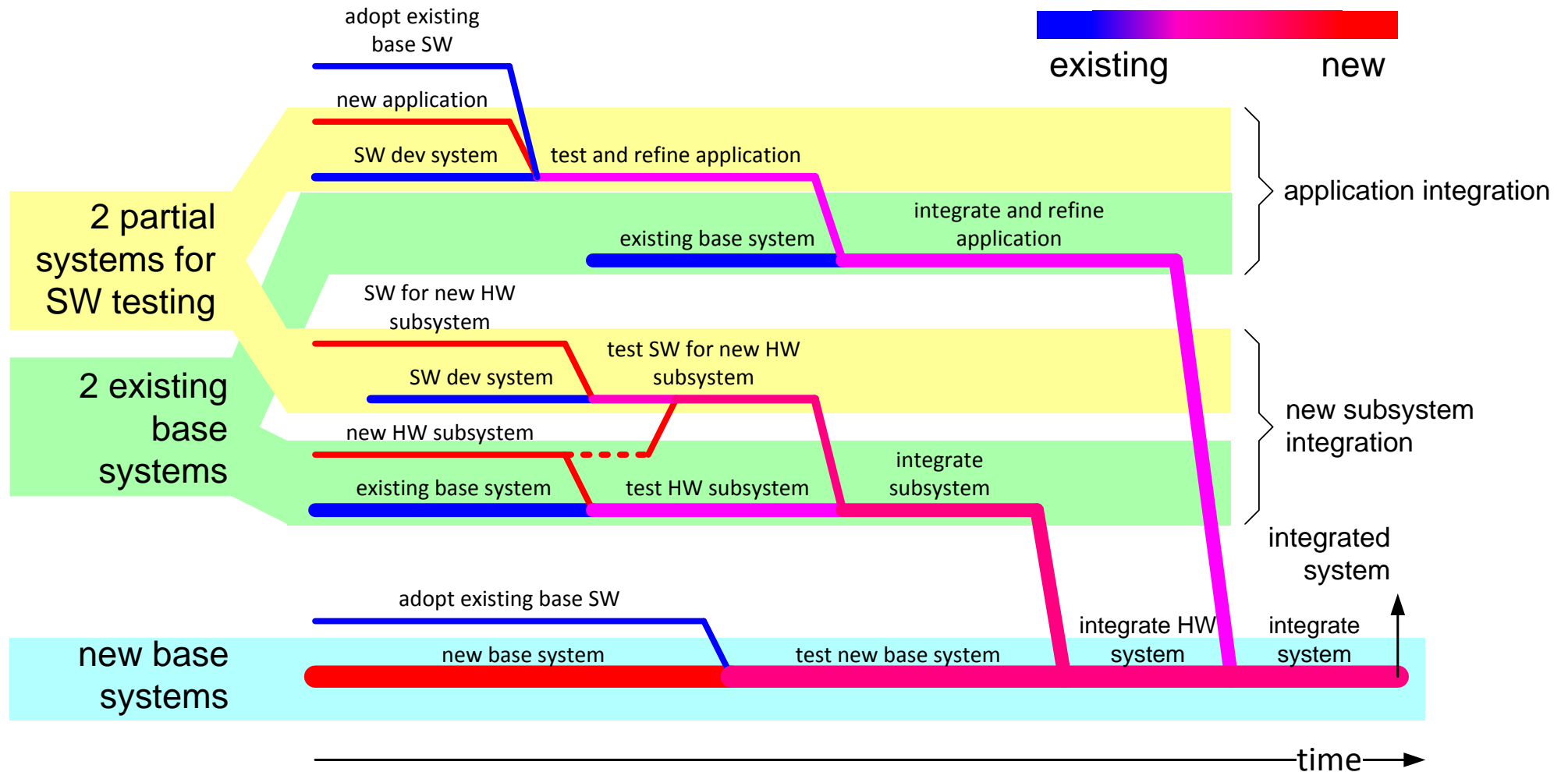
Segregation of hardware and software is a typical organizational problem.

Such segregation ignores close coupling of hardware and software.

Erroneous assumptions about hardware are discovered late.

Key performance parameters are visible late.

Transition from Previous System to New System



Mastering Systems Integration; Terminology

by *Gerrit Muller* [TNO-ESI, University of South-Eastern Norway]

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Abstract

This presentation defines terms, which are used in relation to systems integration, such as validation, verification, qualification, evidence, approval process, certification, and acceptance.

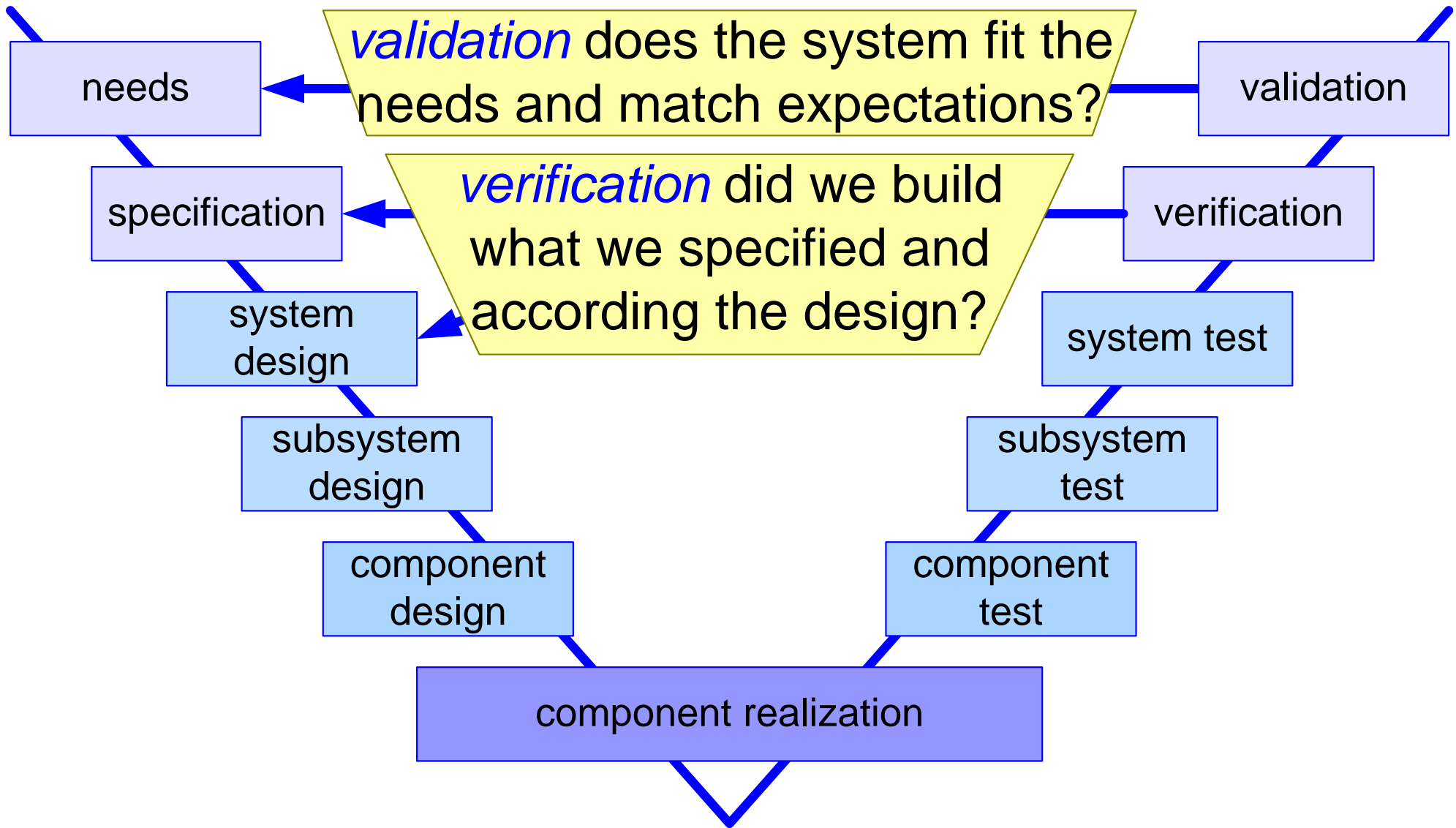
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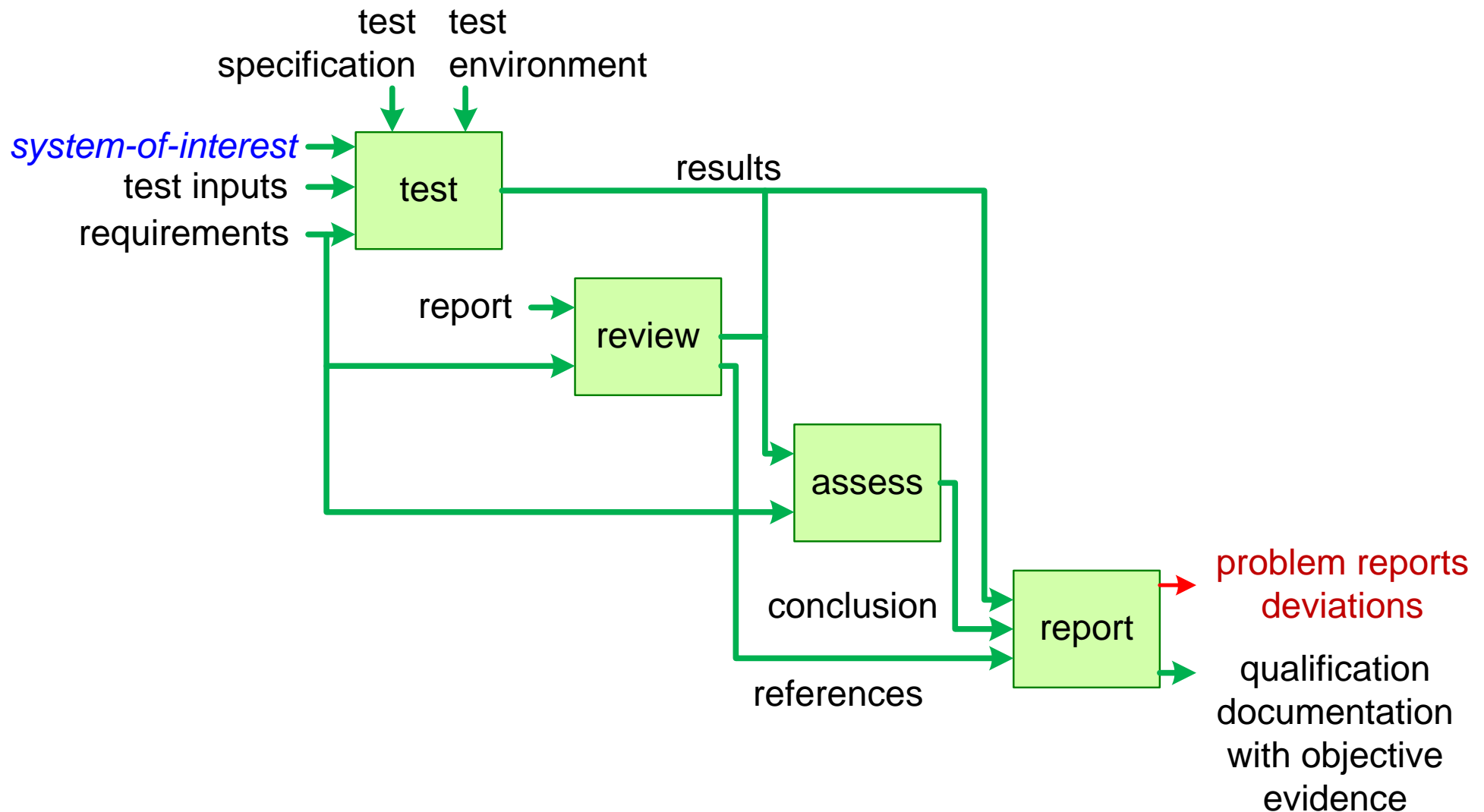
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version: 0

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TBD

Validation and Verification in the V-model



Functional Model of Verification



Certification

Certification: an independent agency (e.g. DNV-GL) certifies the quality of the system-of-interest, technology, or process

Self-certification: the company has been accredited by the agency to do the certification themselves.

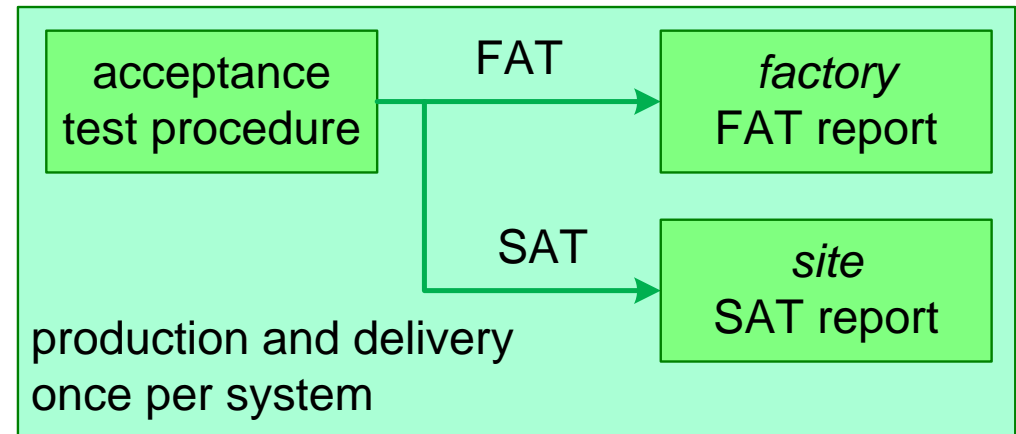
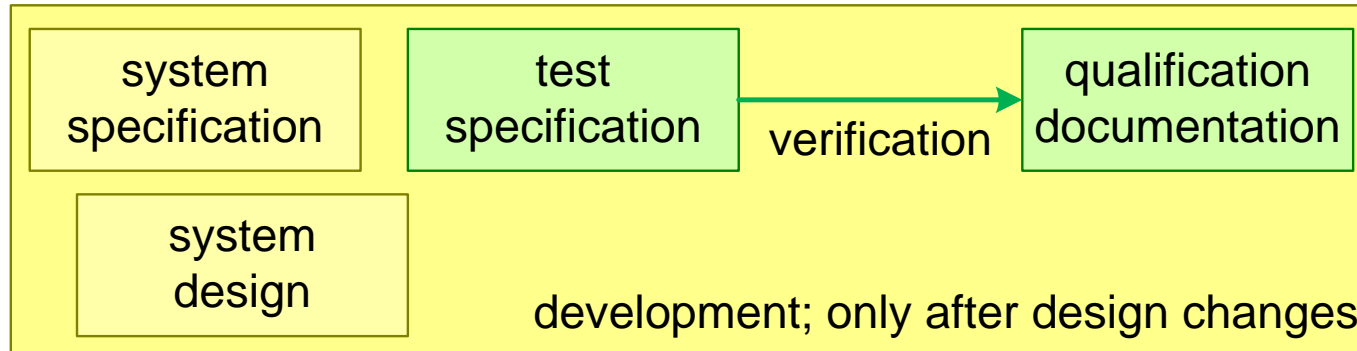
check
qualification data

check process
and organization

optional audit

certify

Development and (repeated) Production



Objective Evidence

From a business perspective: Objective evidence is “information based on facts that can be proved through analysis, measurement, observation, and other such means of research.”

From a legal perspective: Objective evidence is “real evidence, also known as demonstrative or objective evidence; this is naturally the most direct evidence.”

From a scientific perspective: “To be termed scientific, a method of inquiry must be based on gathering observable, empirical, and measurable evidence subject to specific principles of reasoning. A scientific method consists of the collection of data through observation and experimentation, and the formulation and testing of hypotheses.”

From a list of Plain English definitions related to the ISO 9000, 9001 and 9004: Objective evidence is “data that show or prove that something exists or is true. Objective evidence can be collected by performing observations, measurements, tests, or by using any other suitable method.”

from: Understanding Objective Evidence: (What It Is and What It Definitely Is Not),
by Denise Dion http://www.eduquest.net/Advisories/EduQuest%20Advisory_ObjectiveEvidence.pdf

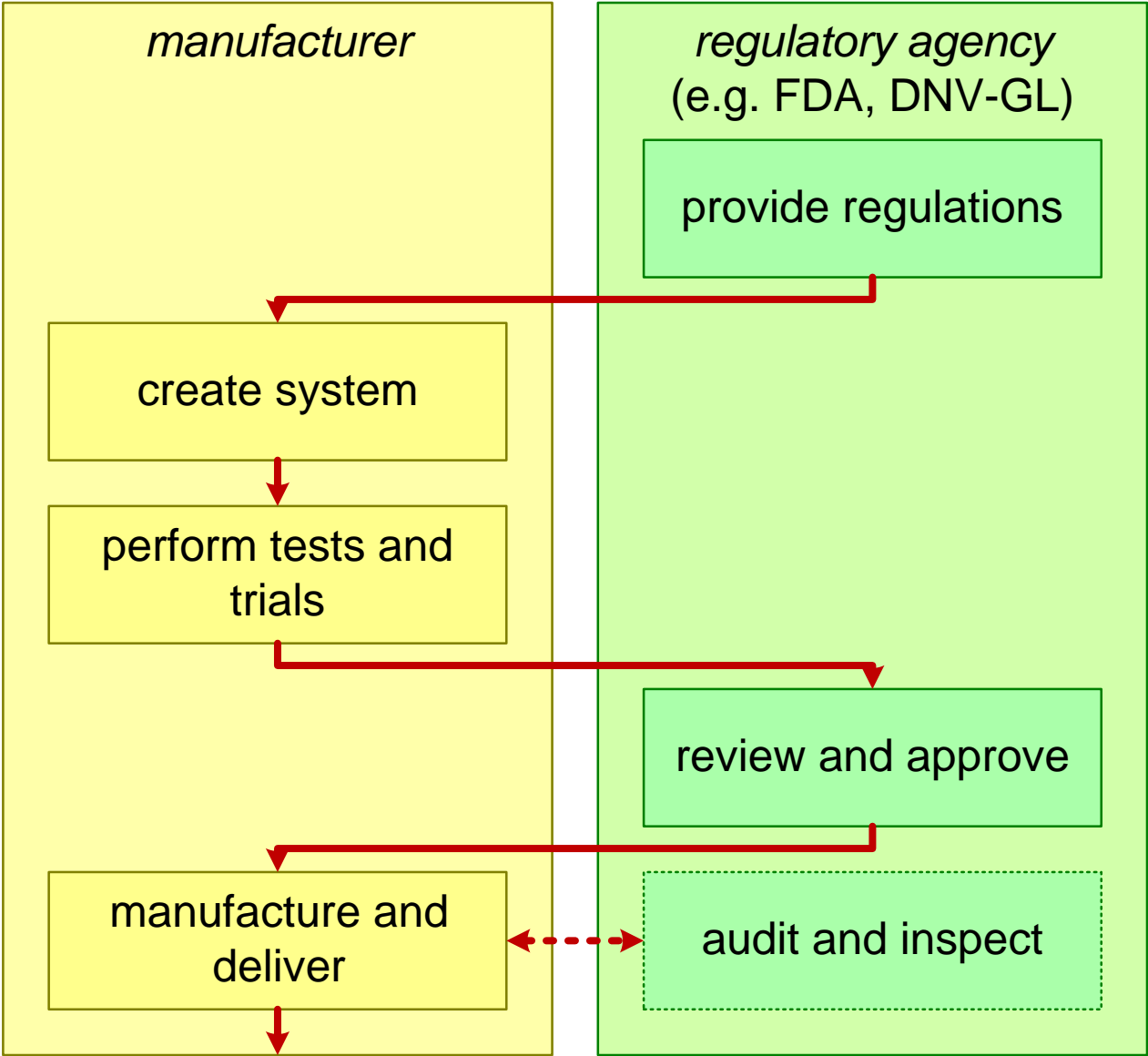
FDA Requirements for Objective Evidence

FDA is a science-based law enforcement agency and, therefore, requires answers that are scientifically and legally supported. FDA expects your objective data to answer the following questions:

- **Scientific** – Can the data be *evaluated by independent observers* to reach the same conclusions?
- **Scientific** – Are the data documented in a manner that *allows re-creation of the data* or the events described?
- **Scientific** – Does the documented evidence provide *sufficient data* to prove what happened, when, by whom, how, and why?
- **Legal** – Was the documentation *completed concurrently* with the tasks?
- **Legal** – Is the documentation *attributable* (directly traceable to a person)?
- **Legal** – Have the data and associated documentation been maintained in a manner that *provides traceable evidence* of changes, deletions, additions, substitutions, or alterations?
- **Legal** – Are the data and associated documentation maintained in a manner that *protects and secures* them from changes, deletions, additions, substitutions, or alterations?

from: Understanding Objective Evidence: (What It Is and What It Definitely Is Not),
by Denise Dion http://www.eduquest.net/Advisories/EduQuest%20Advisory_ObjectiveEvidence.pdf

Regulatory Approval Process



Mastering Systems Integration; Economic Perspective

by *Gerrit Muller* [TNO-ESI, University of South-Eastern Norway]

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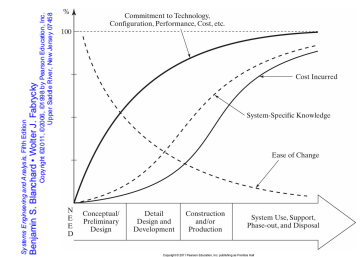
Abstract

This presentation discusses economic aspects related to integration.

Distribution

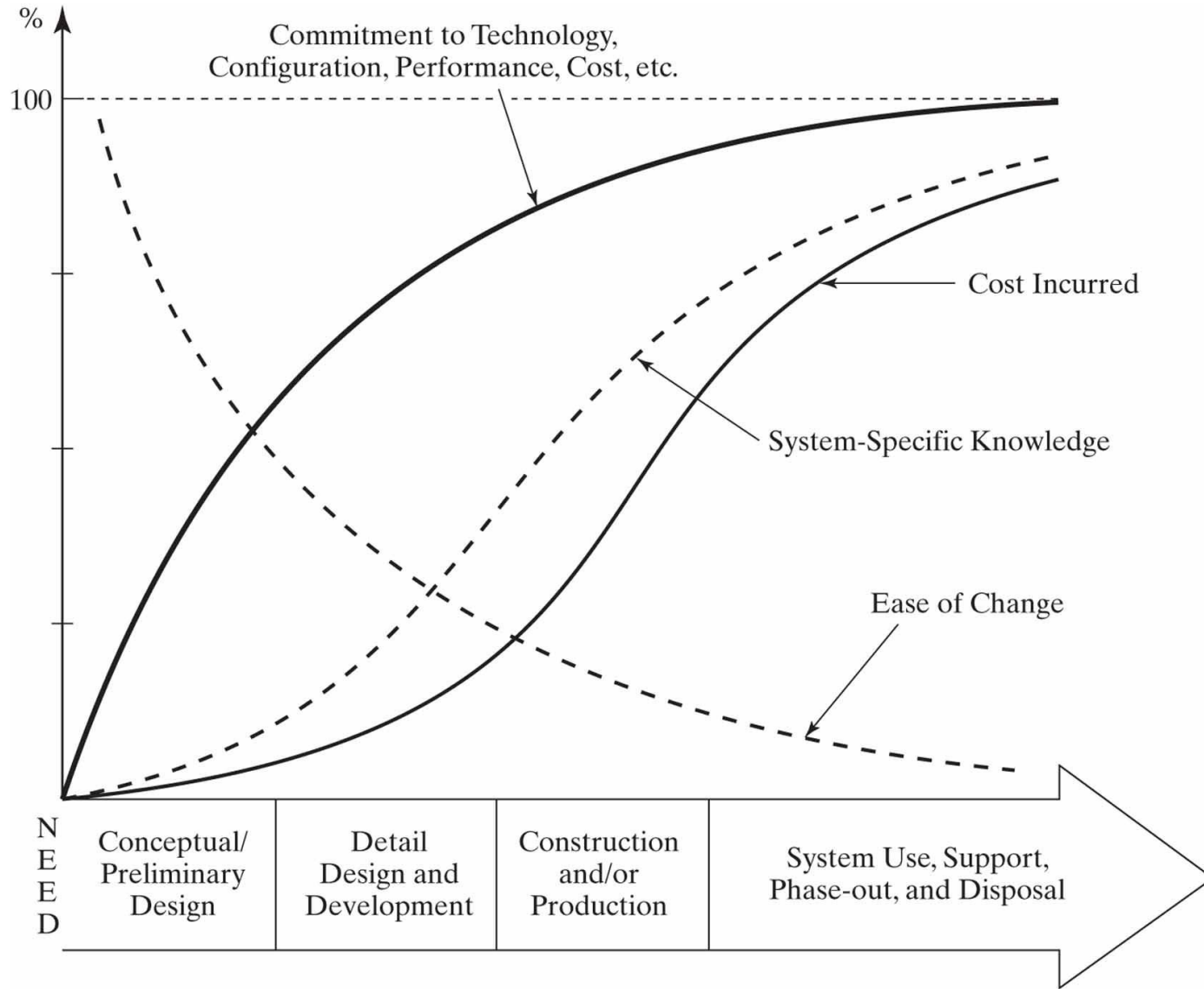
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status: planned
version: 0.1



Life-cycle commitment, knowledge, and incurred cost

Systems Engineering and Analysis, Fifth Edition
 Benjamin S. Blanchard • Wolter J. Fabrycky
 Copyright © 2011, © 2006, © 1998 by Pearson Education, Inc.
 Upper Saddle River, New Jersey 07458



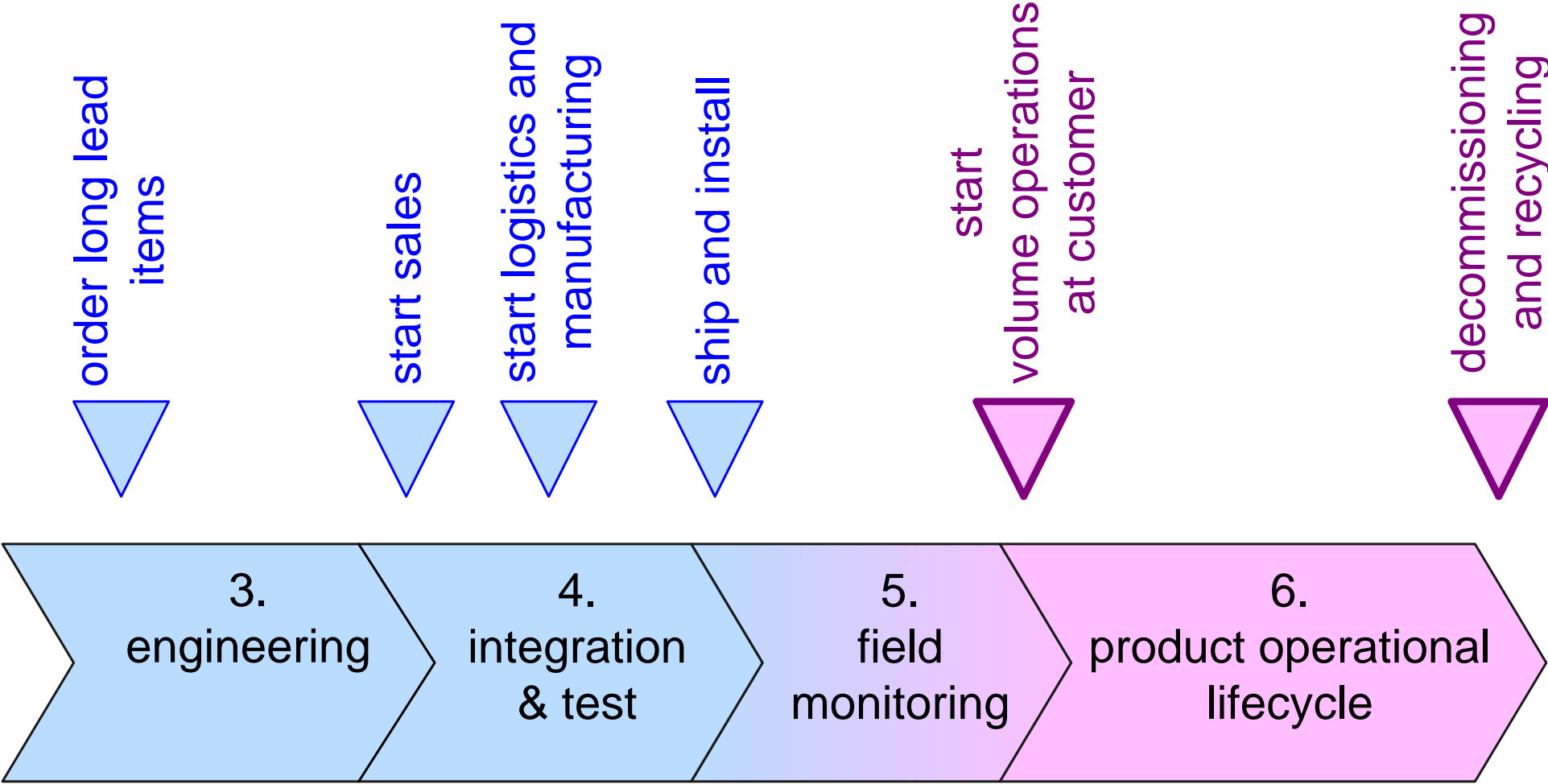
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Importance of Time to Market

- No loss of value by customer
- Return on investment & profit ASAP
- Competitive edge, market share
- Free up critical resources for next projects ASAP
- Obsolescence

Cost Related Milestones

What knowledge does the project need to make these critical steps?



Visualizing Dynamic Behavior

by *Gerrit Muller* [TNO-ESI, University of South-Eastern Norway]

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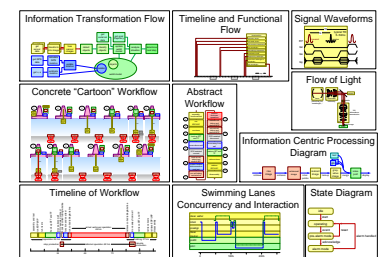
Abstract

Dynamic behavior manifests itself in many ways. Architects need multiple complementary visualizations to capture dynamic behavior effectively. Examples are capturing information, material, or energy flow, state, time, interaction, or communication.

Distribution

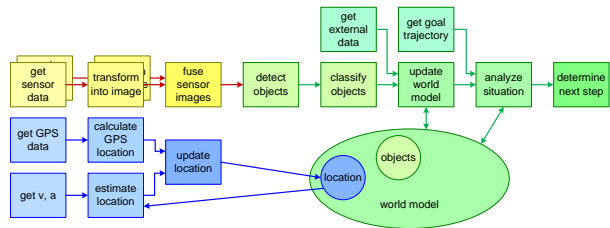
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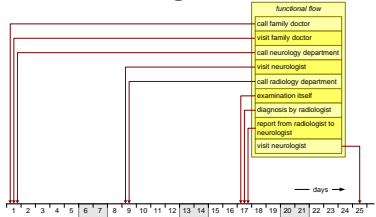


Overview of Visualizations of Dynamic Behavior

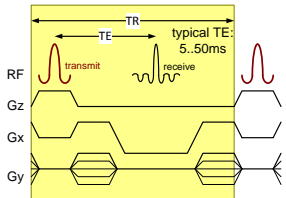
Information Transformation Flow



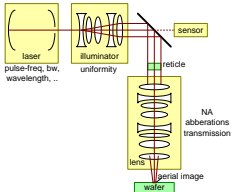
Timeline and Functional Flow



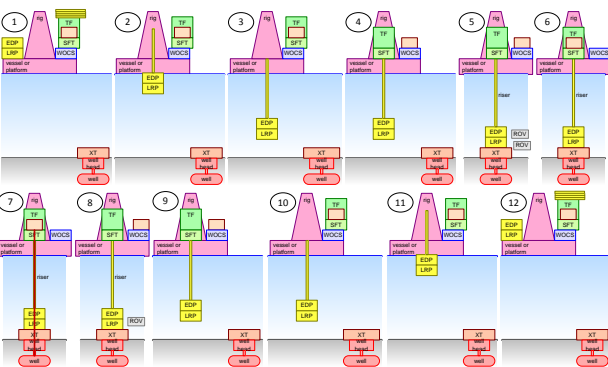
Signal Waveforms



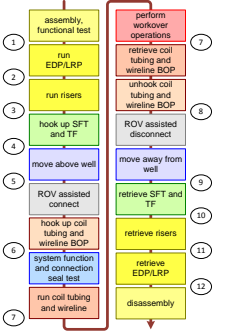
Flow of Light



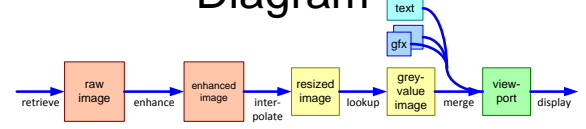
Concrete "Cartoon" Workflow



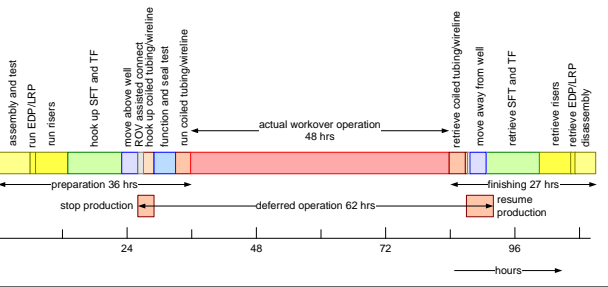
Abstract Workflow



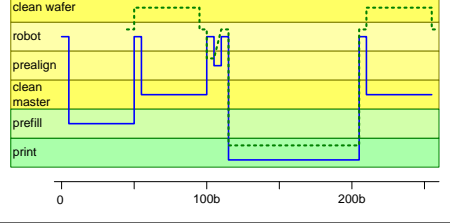
Information Centric Processing Diagram



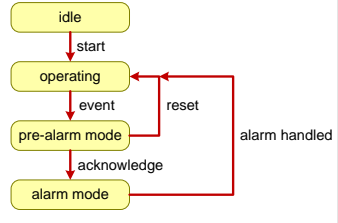
Timeline of Workflow



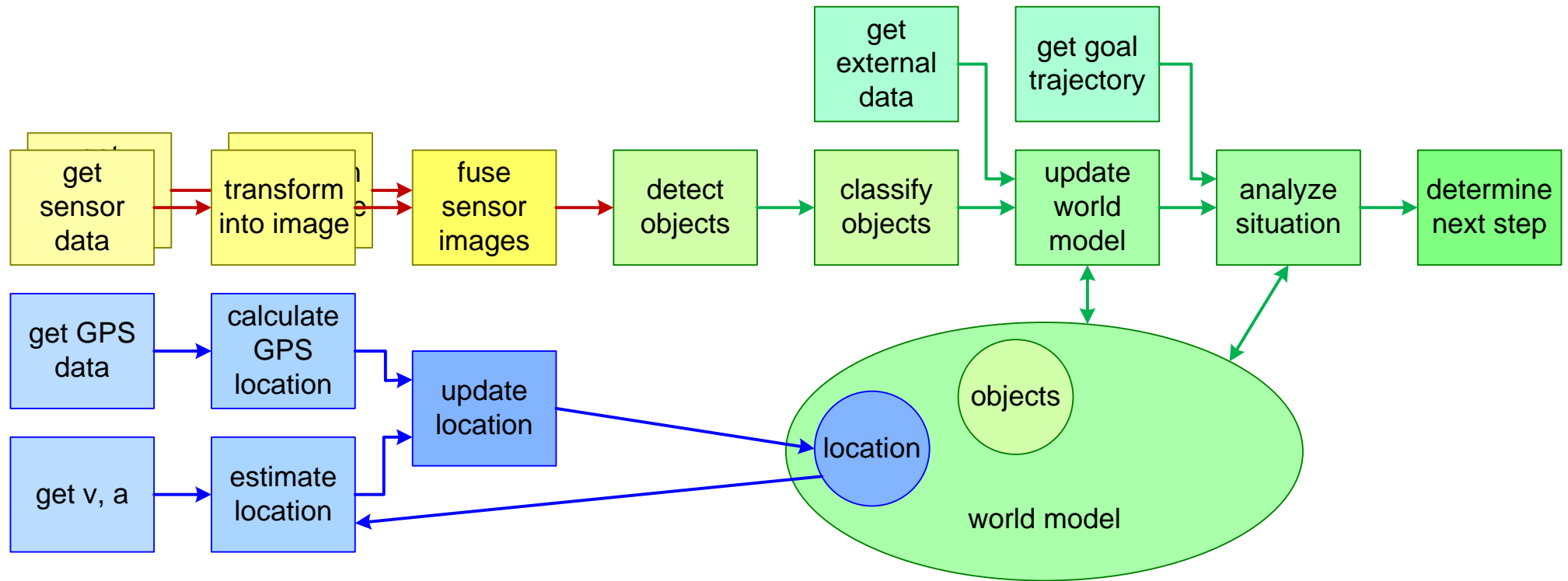
Swimming Lanes Concurrency and Interaction



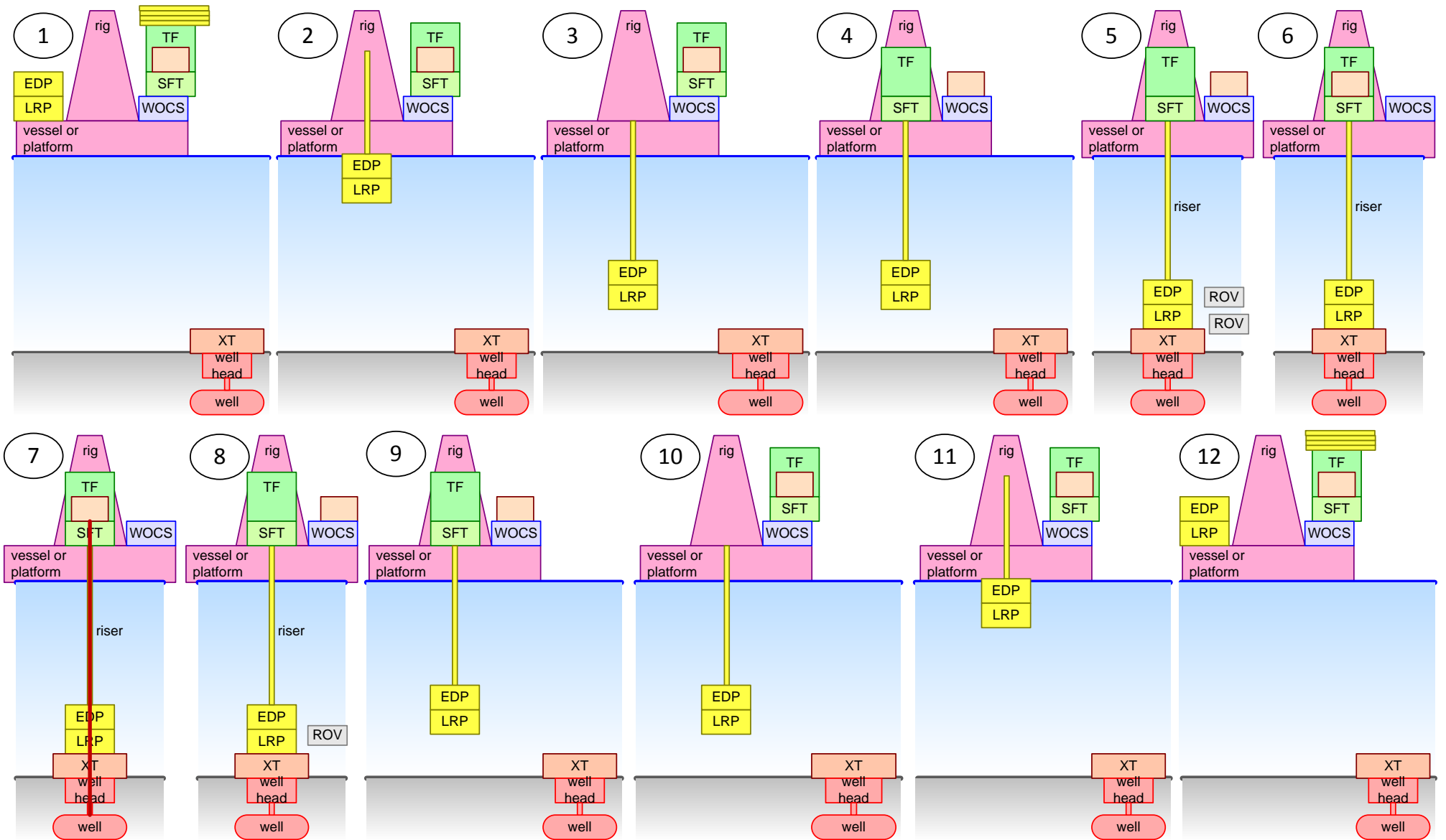
State Diagram



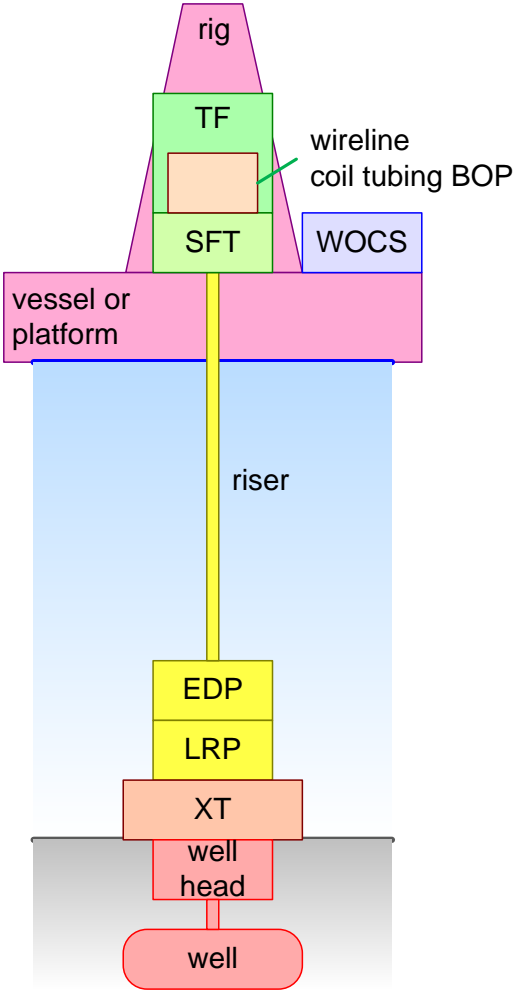
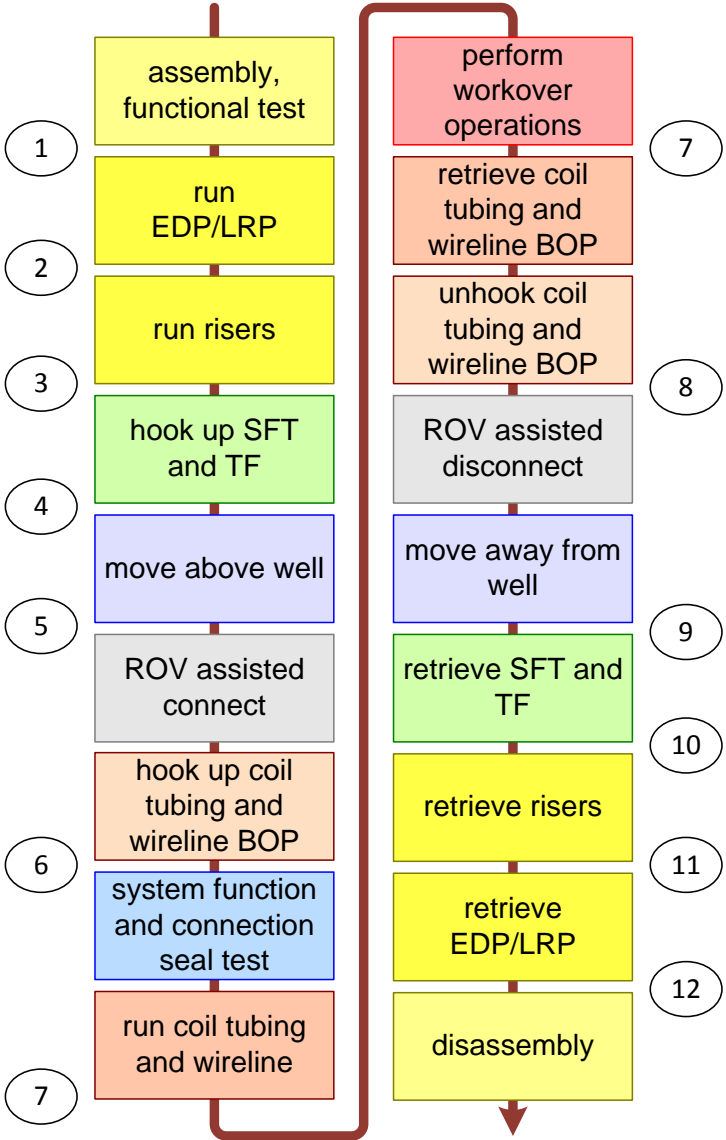
Example Functional Model of Information Flow



"Cartoon" Workflow



Workflow as Functional Model

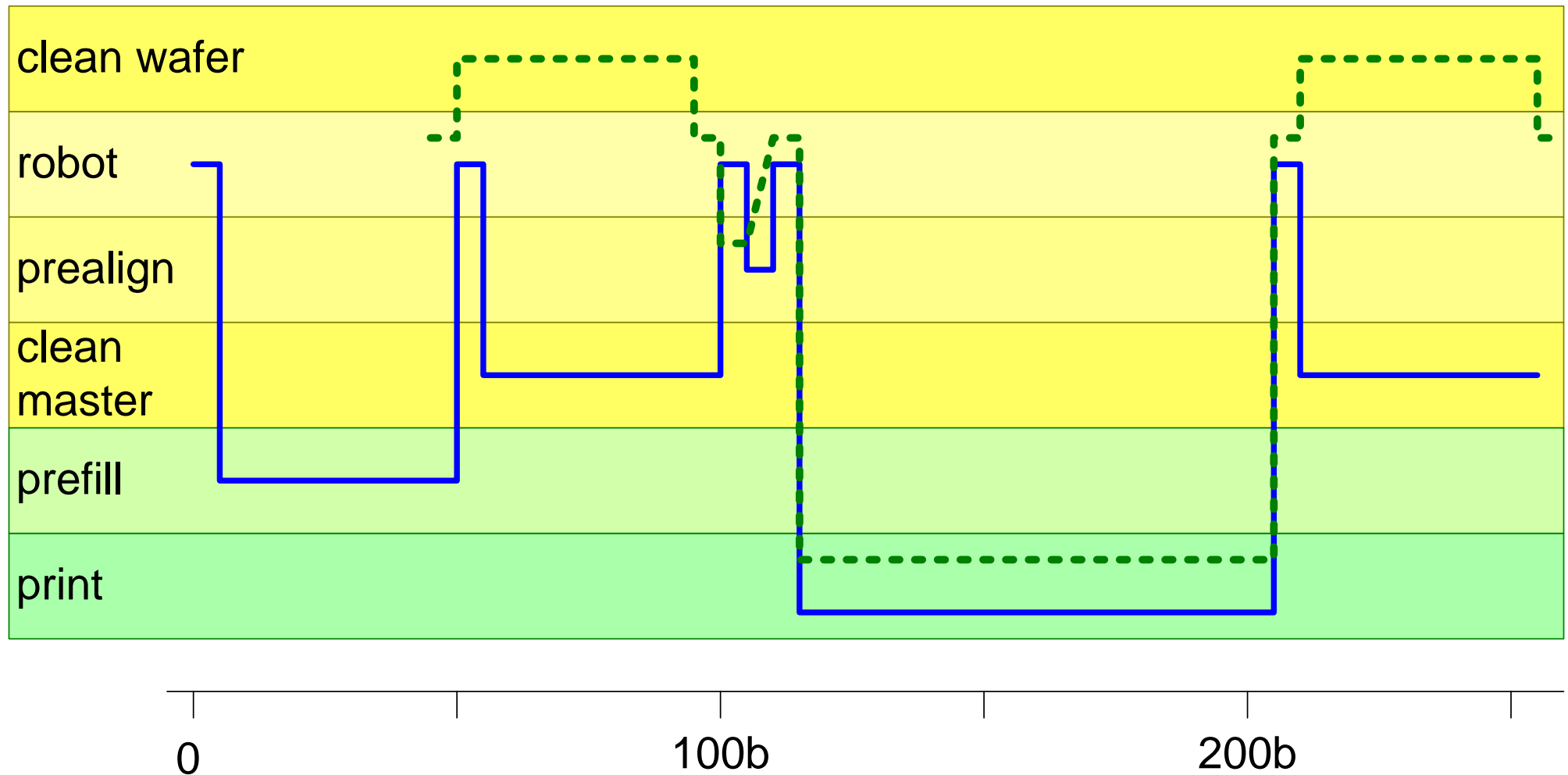


Workflow as Timeline

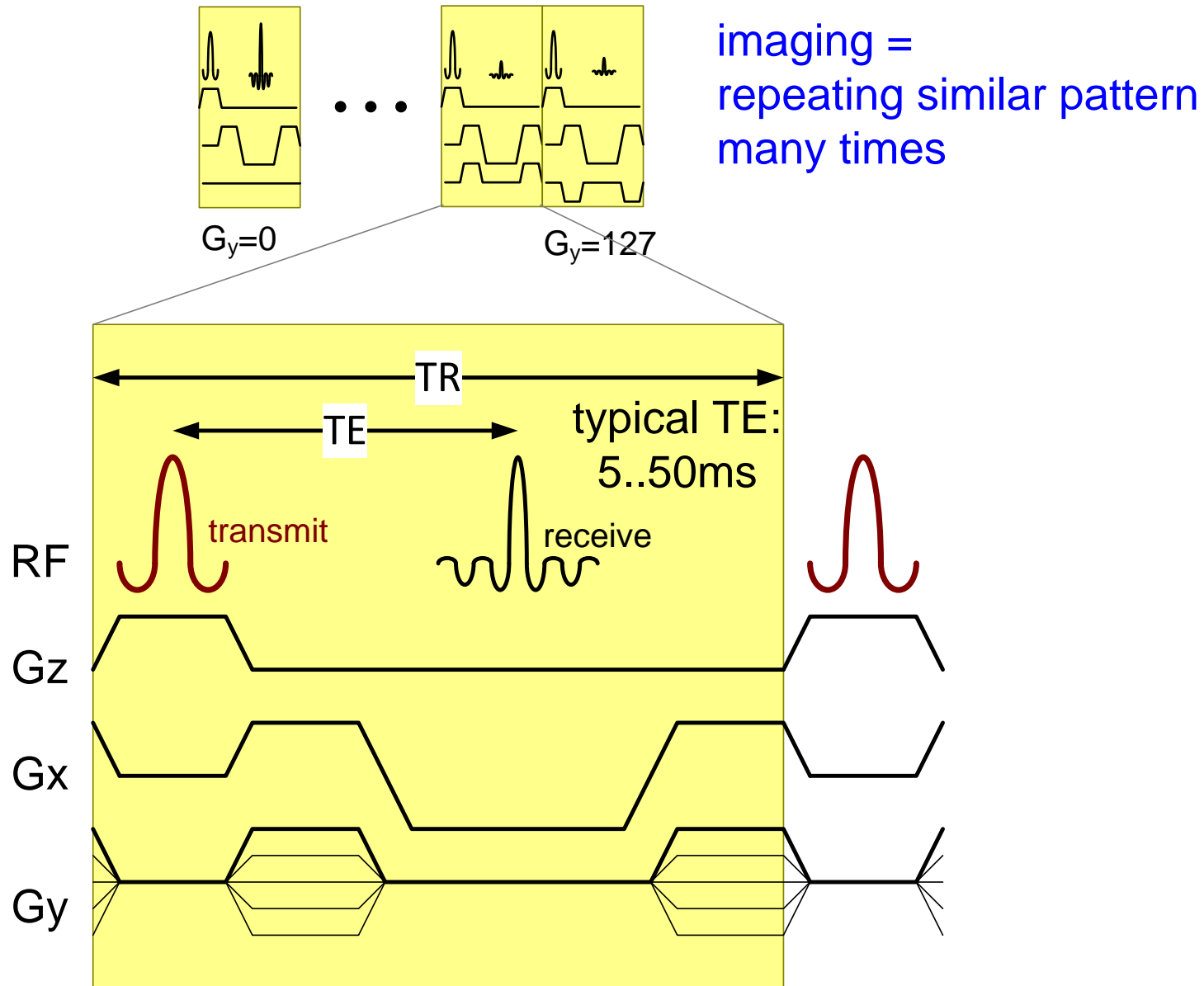
assumptions:
 running and retrieving risers: 50m/hr
 running and retrieving coiled tubing/wireline: 100m/hr
 depth: 300m



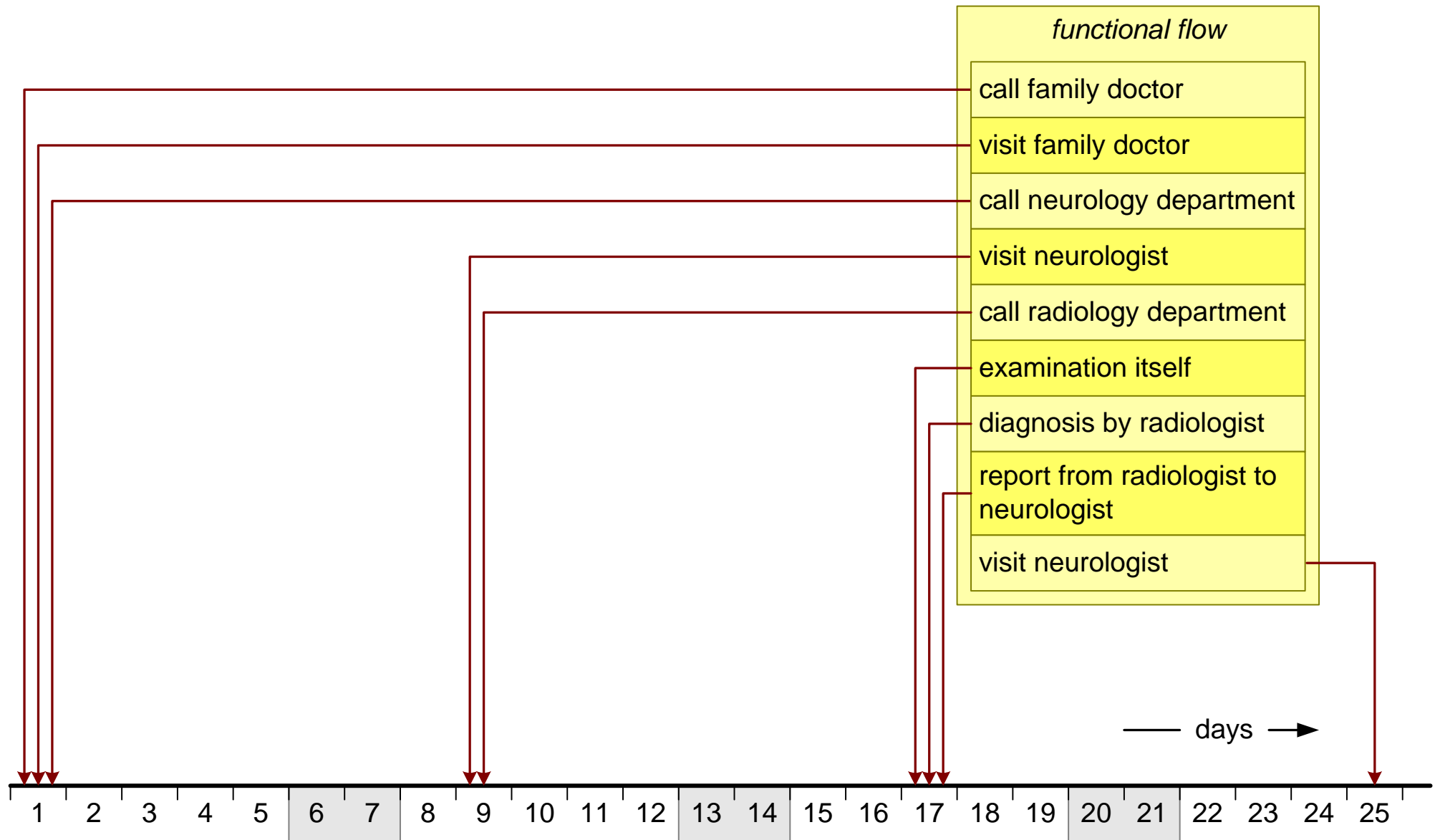
Swimming Lane Example



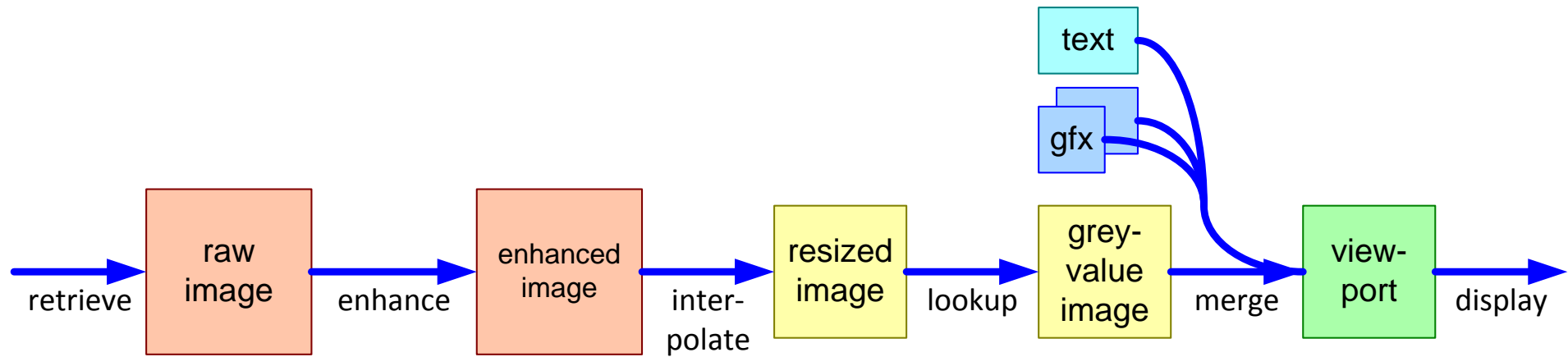
Example Signal Waveforms



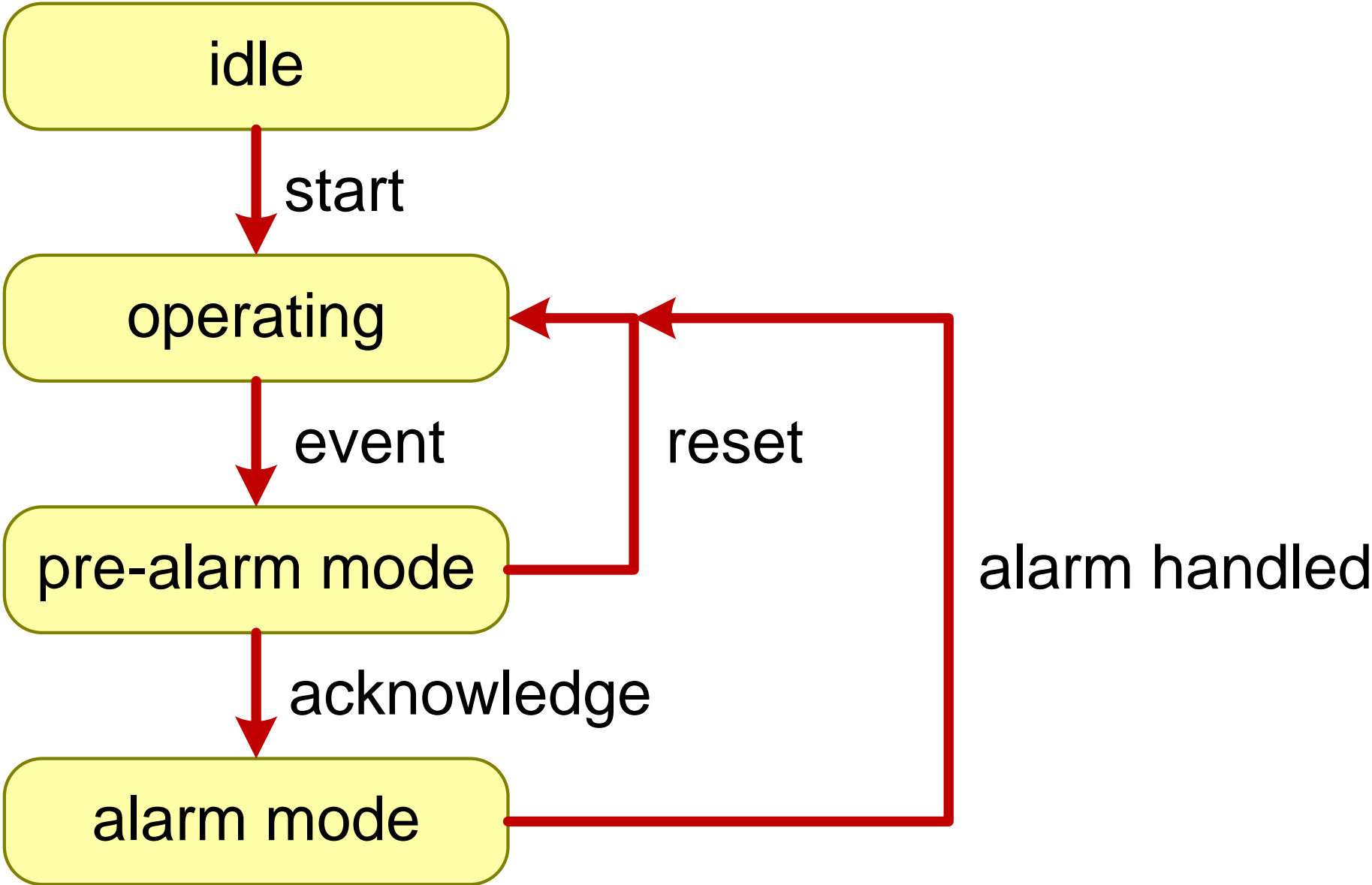
Example Time Line with Functional Model



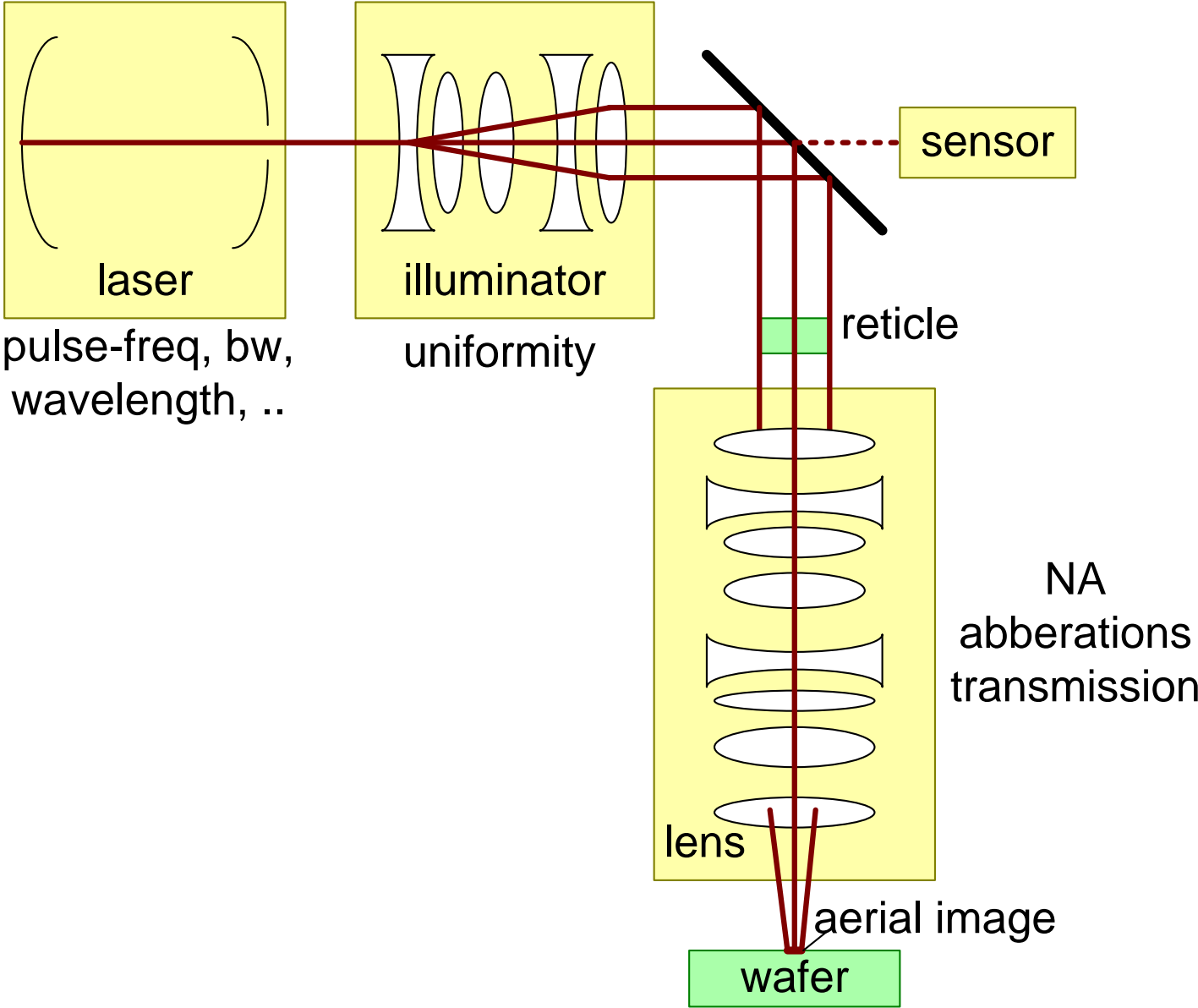
Information Centric Processing Diagram



Example State Diagram



Flow of Light (Physics)



Dynamic Behavior is Multi-Dimensional

How does the system work and operate?

Functions describe *what* rather than *how*.

Functions are *verbs*.

Input-Process-Output paradigm.

Multiple kinds of flows:

physical (e.g. hydrocarbons, goods, energy)

information (e.g. measurements, signals)

control

Time, events, cause and effect

Concurrency, synchronization, communication

multi-dimensional
information and
dynamic behavior

Mastering Systems Integration; Early Validation

by *Gerrit Muller* TNO-ESI, USN-SE

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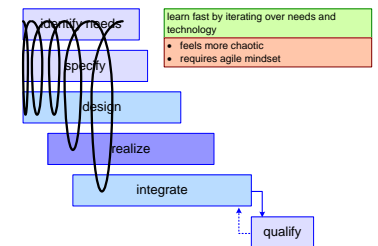
Abstract

The core principle of systems integration is early validation; are the assumptions of the needs, specifications and design decisions valid? it is better to fail early, then to hit faulty assumptions, unknowns, or uncertainties late in development.

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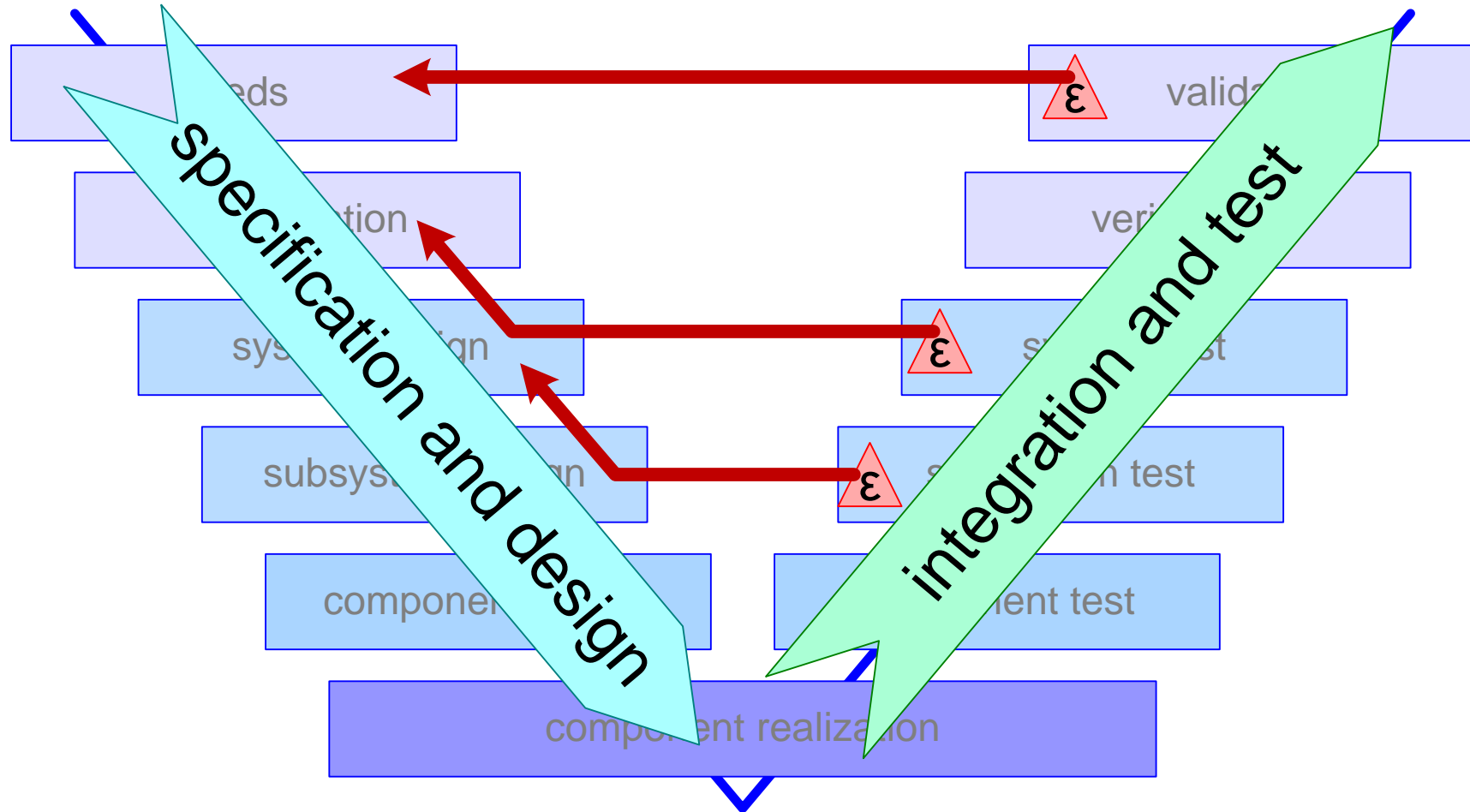
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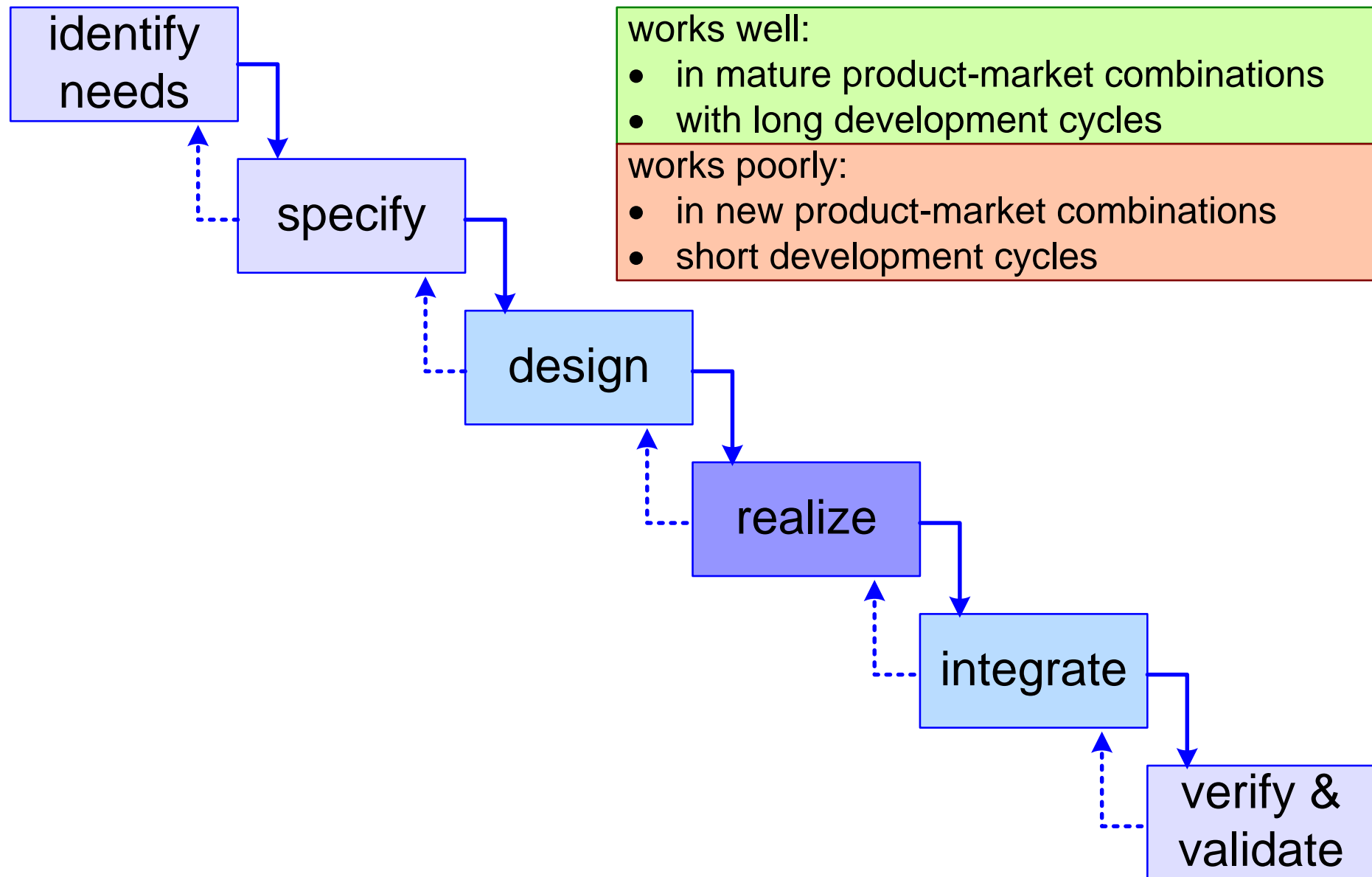


Most Problems are Found Late

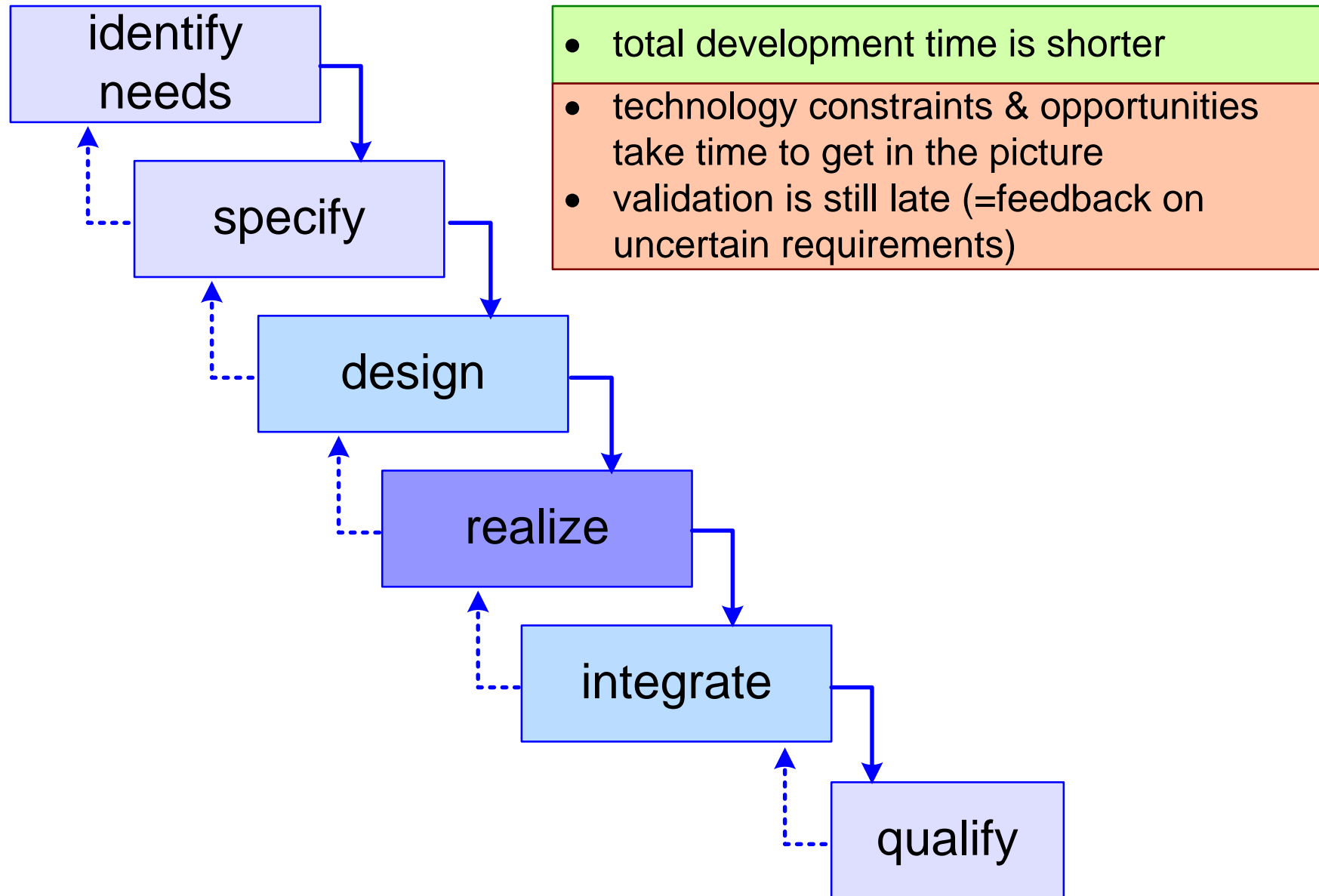
failures found during integration and test can be traced back to unknowns, unforeseens, and wrong assumptions



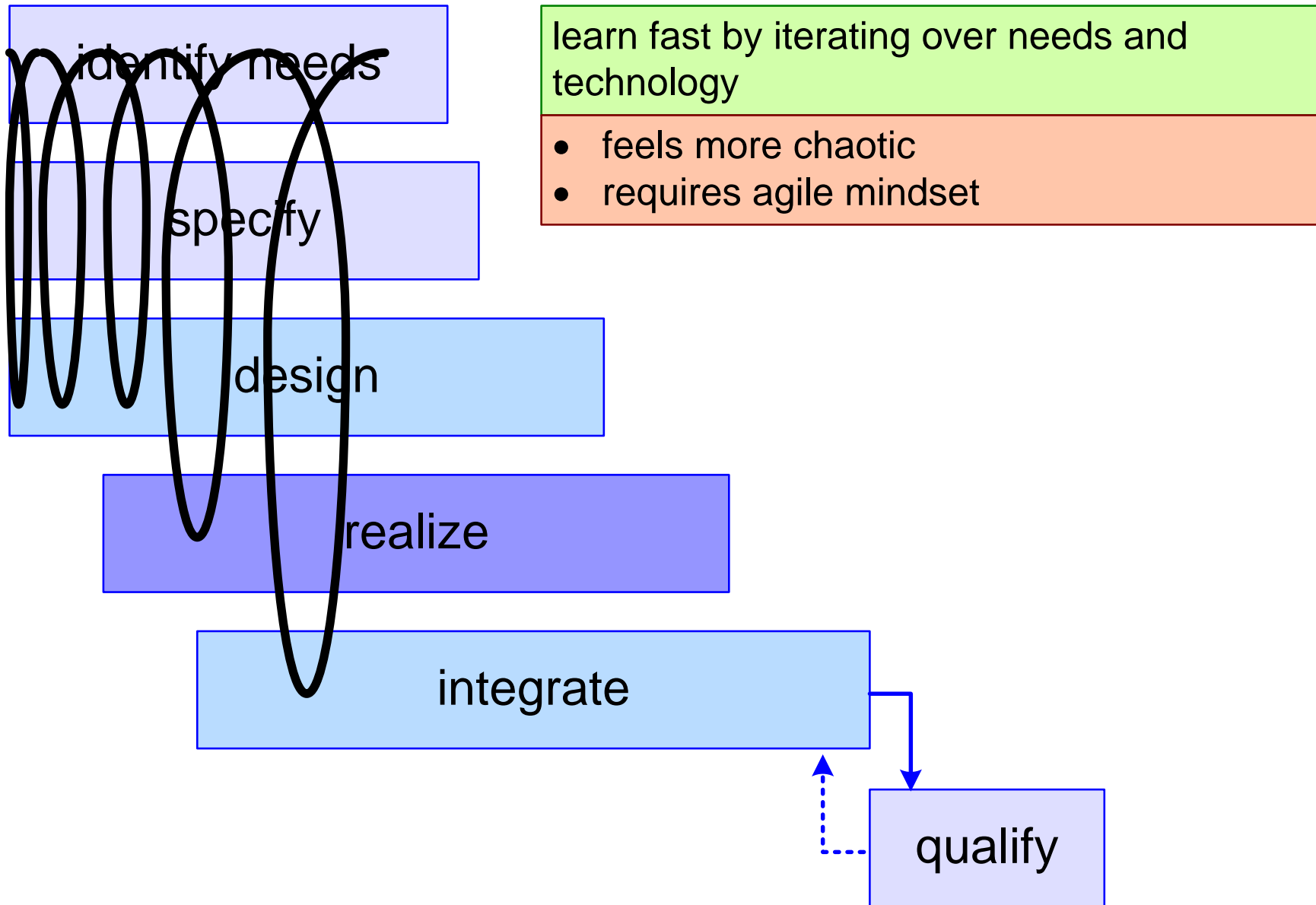
Waterfall model



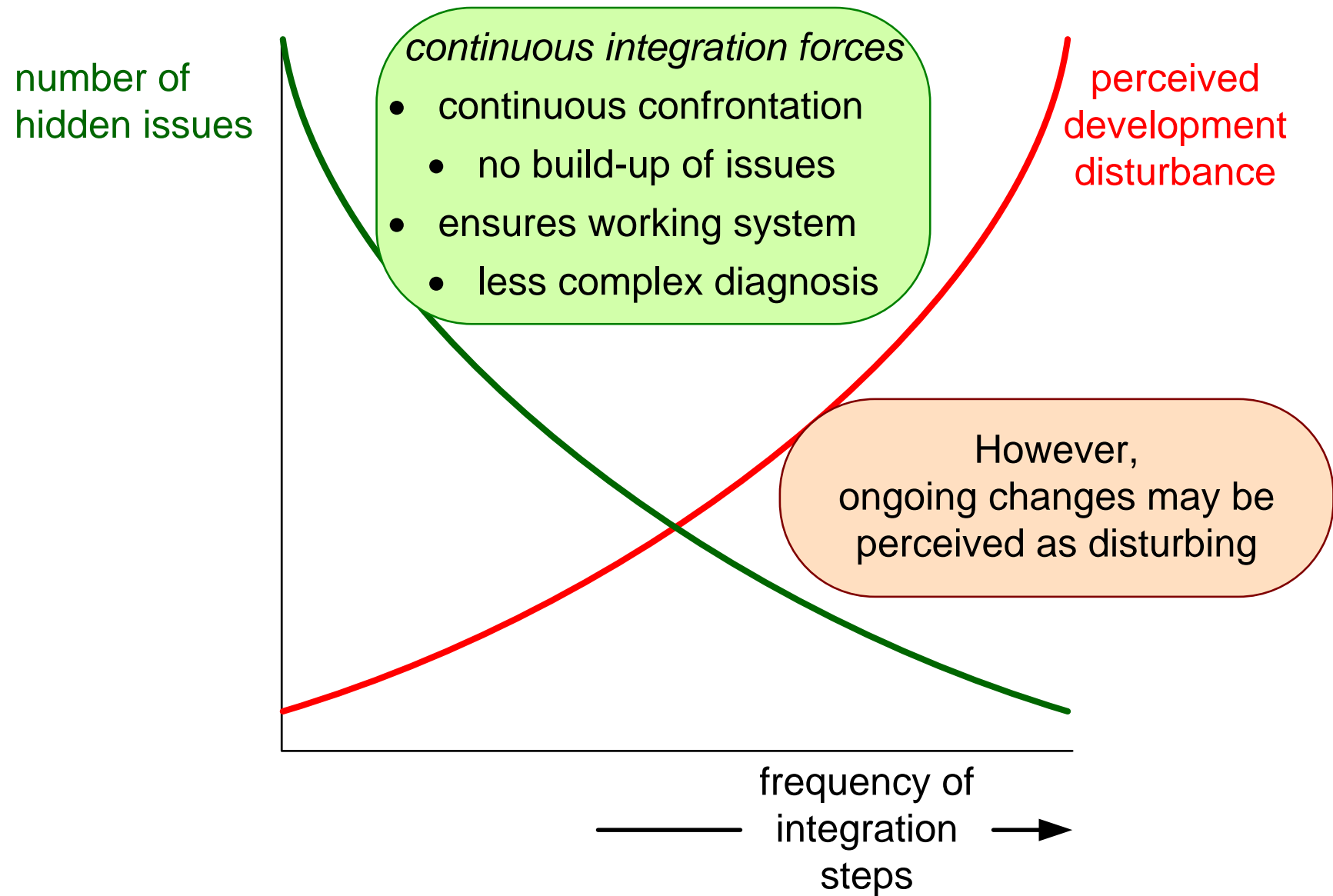
Concurrent Engineering



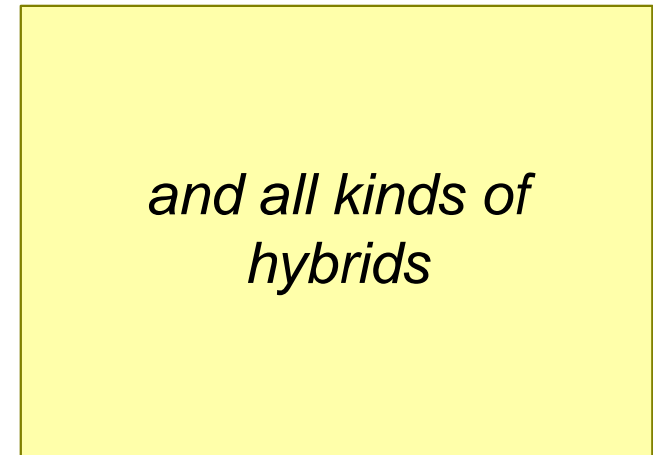
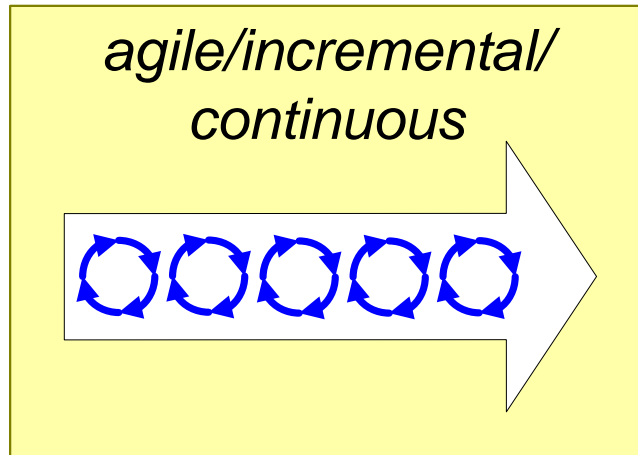
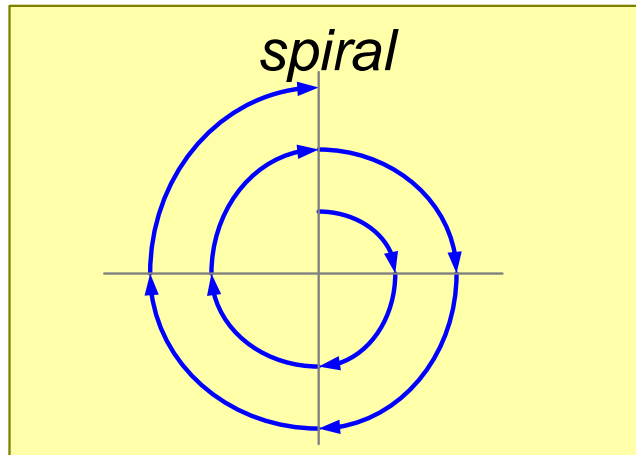
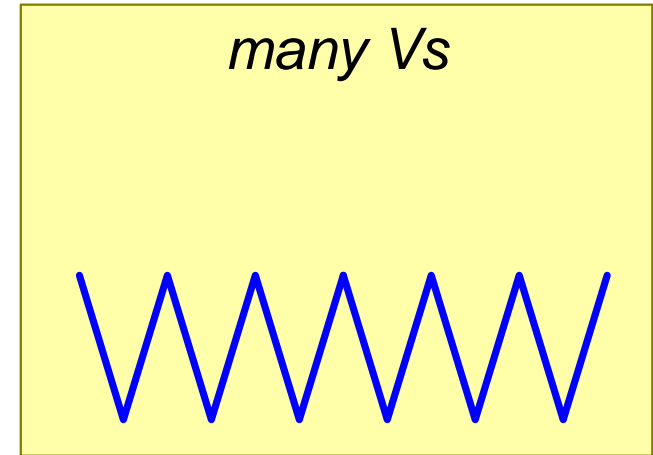
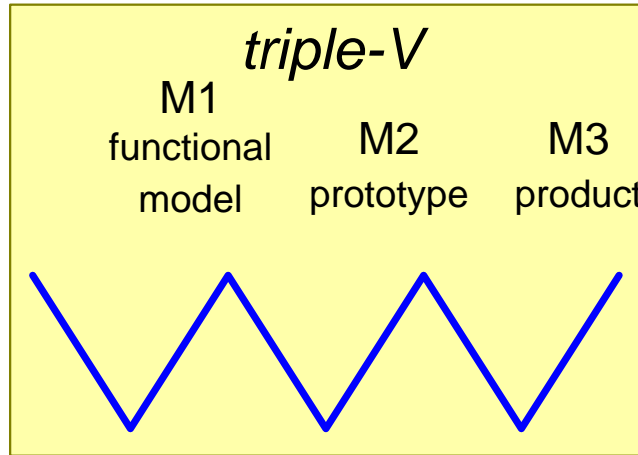
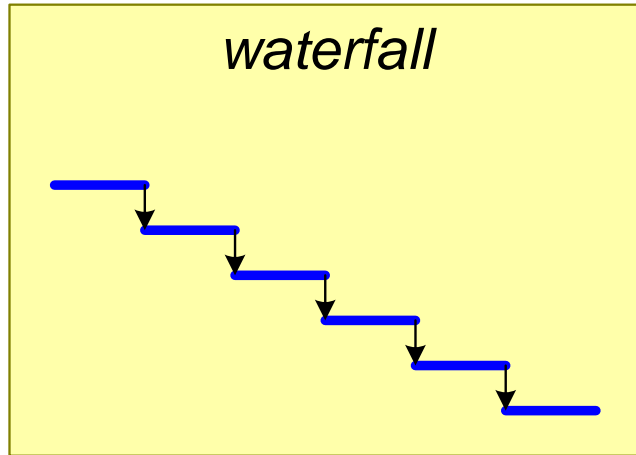
Iterative Approach



Continuous Integration



Development Processes From Waterfall to Agile



Mastering Systems Integration; Integration Strategy

by *Gerrit Muller* [TNO-ESI, University of South-Eastern Norway]

e-mail: `gaudisite@gmail.com`

`www.gaudisite.nl`

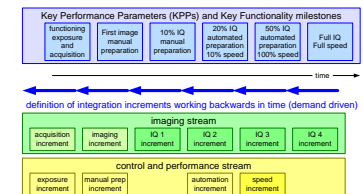
Abstract

This presentations discusses the strategy for integration. The strategy is transformed into an approach to determine an integration sequence based on Key Performance Parameters and potential risks to achieve them.

Distribution

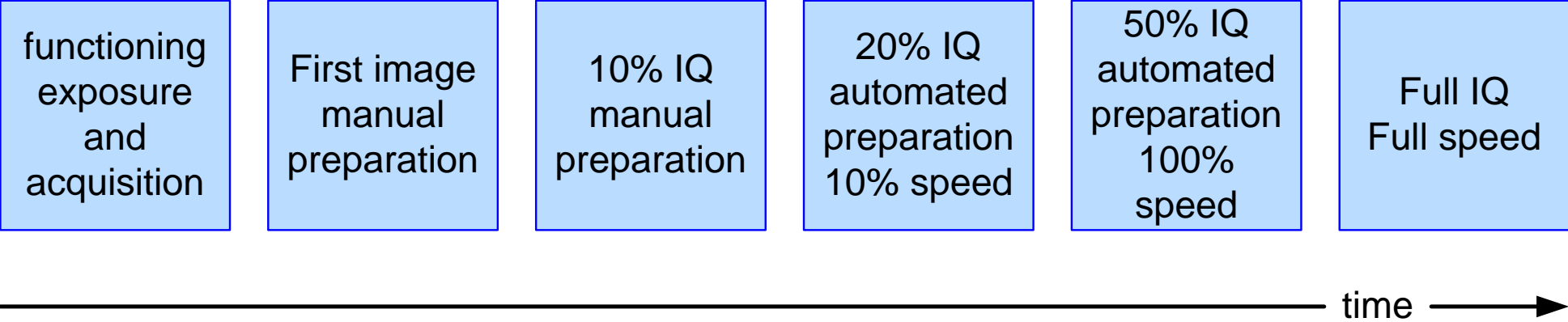
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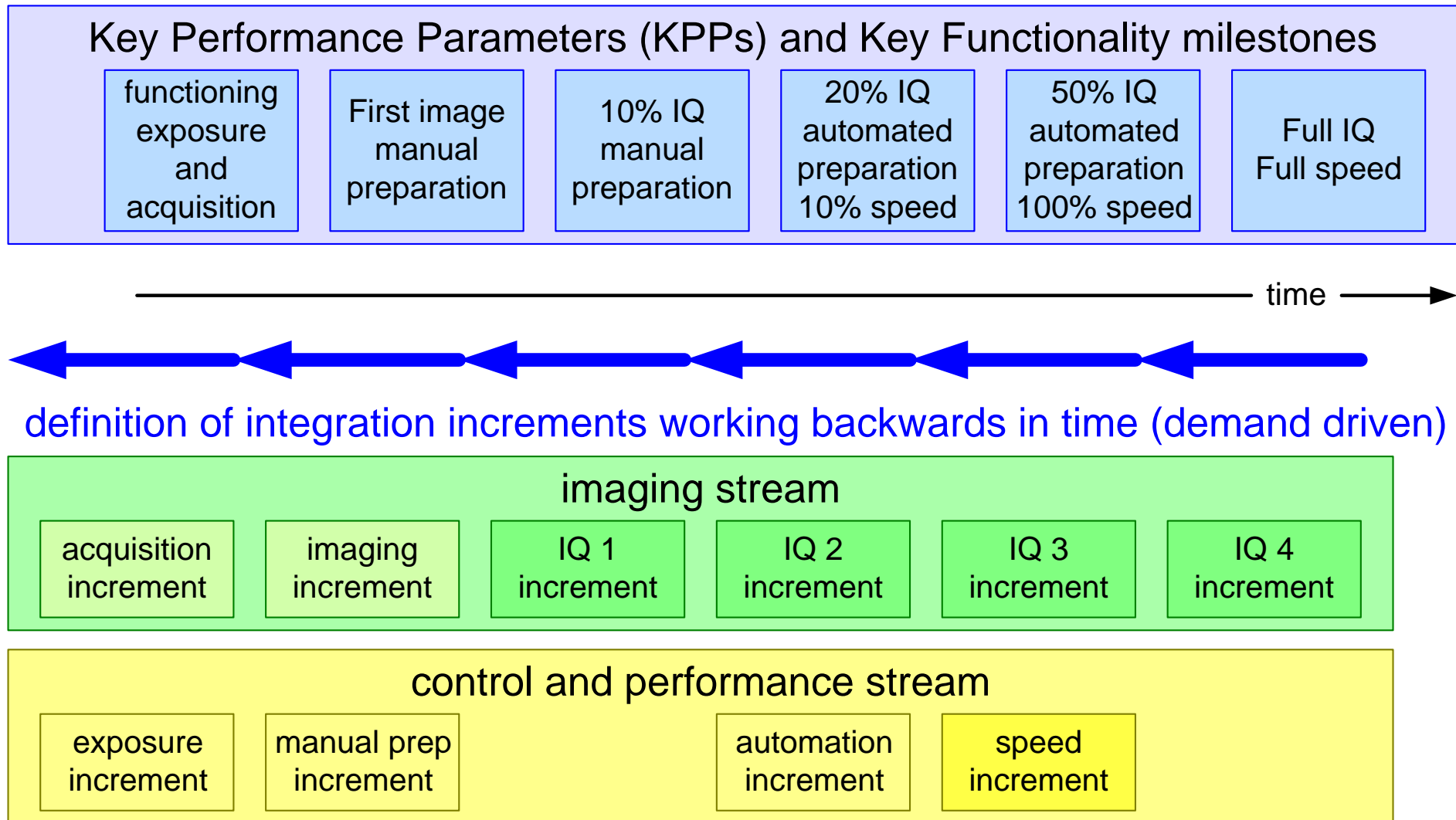
- Get Key Performance Parameters functioning ASAP
- Work on highest risks ASAP
- Use a pacing process (regular visible results)
 - with regular milestones
 - and increments in functionality and performance
- Merge constraints from test configurations, suppliers, resources, etc.

Pacing Milestones



pacing:
maximum 6 month between milestones
depending on technology and domain

Defining an Integration Sequence in Increments



Stepwise Integration Approach

1	Determine most critical system performance parameters.
2	Identify subsystems and functions involved in these parameters.
3	Work towards integration configurations along these chains of subsystems and functions.
4	Show system performance parameter as early as possible; start with showing "typical" system performance.
5	Show "worst-case" and "boundary" system performance.
6	Rework manual integration tests in steps into automated regression tests.
7	Monitor regression results with human-driven analysis.
8	Integrate the chains: show system performance of different parameters simultaneously on the same system.

Mastering Systems Integration; Integration Environments

by *Gerrit Muller* [TNO-ESI, University of South-Eastern Norway]

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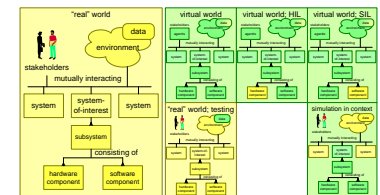
Abstract

Integration requires an environment that serves as vehicle for the integration. Typically, a wide variation of environments supports the integration.

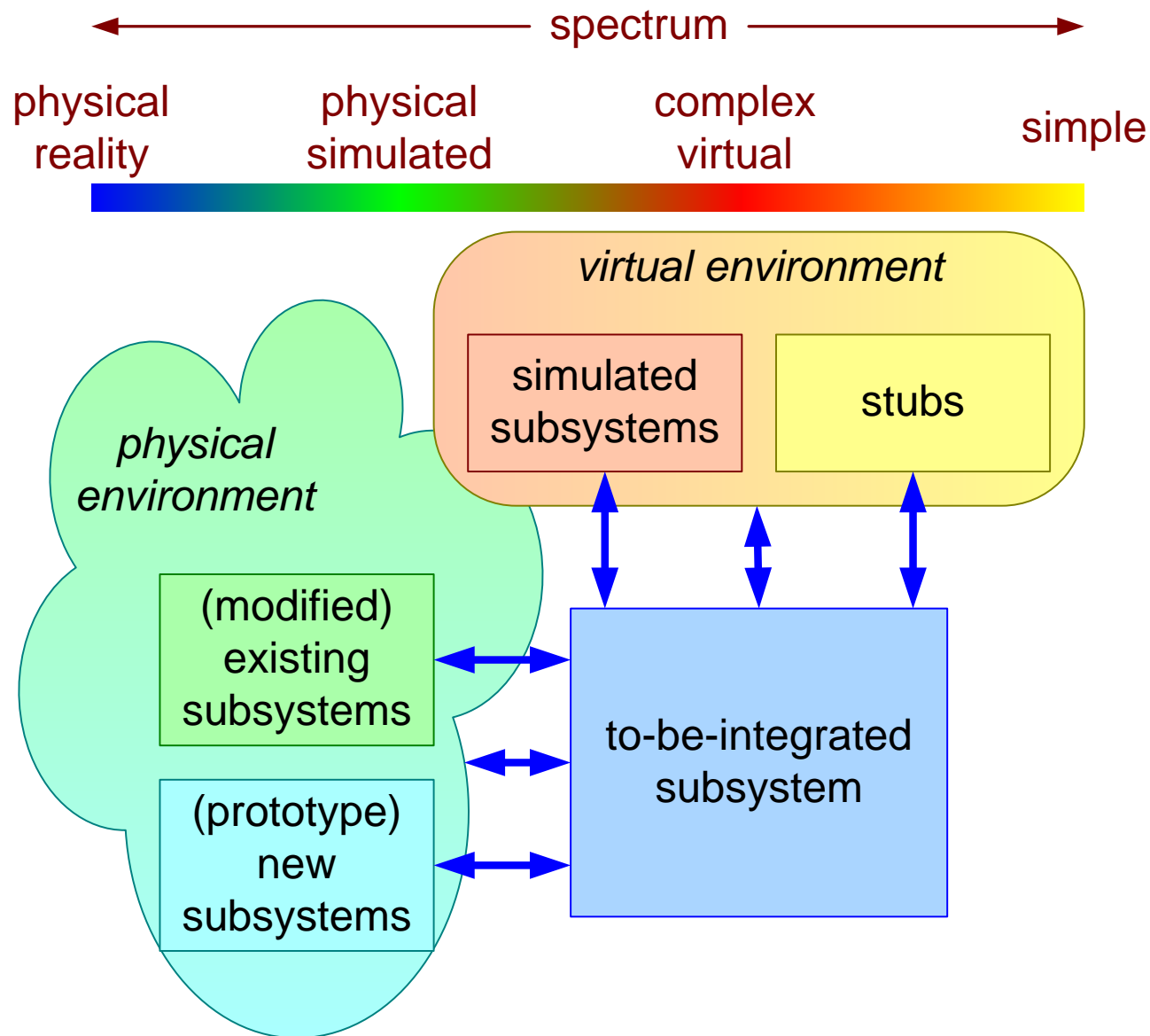
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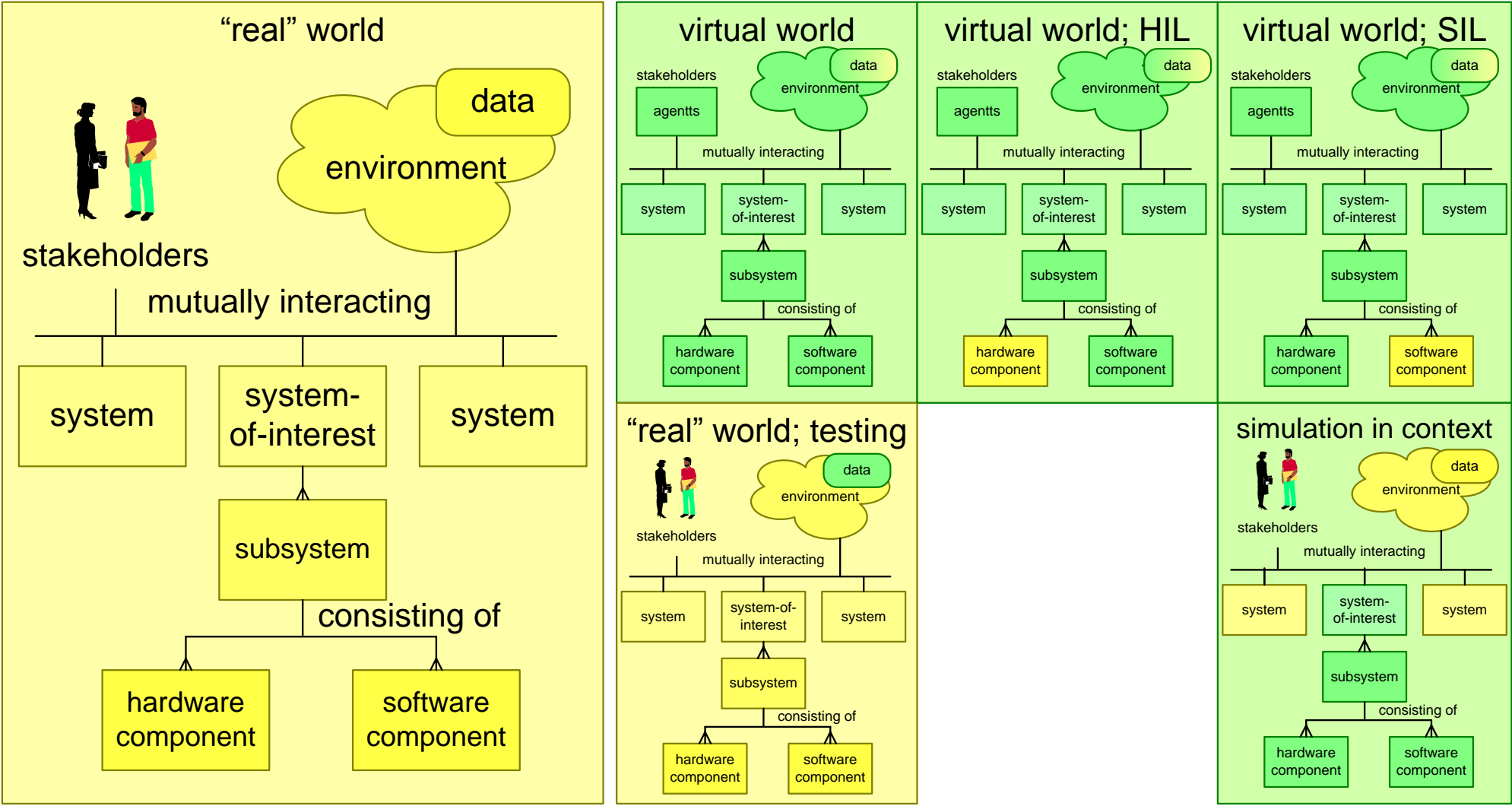
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version: 0.2



Spectrum of Environments to Support Integration



Spectrum from Real to Virtual Systems



Scope of Test Configuration Management

components $10^4..10^6$

functions emerging from components

specifications and designs

infoware

tools

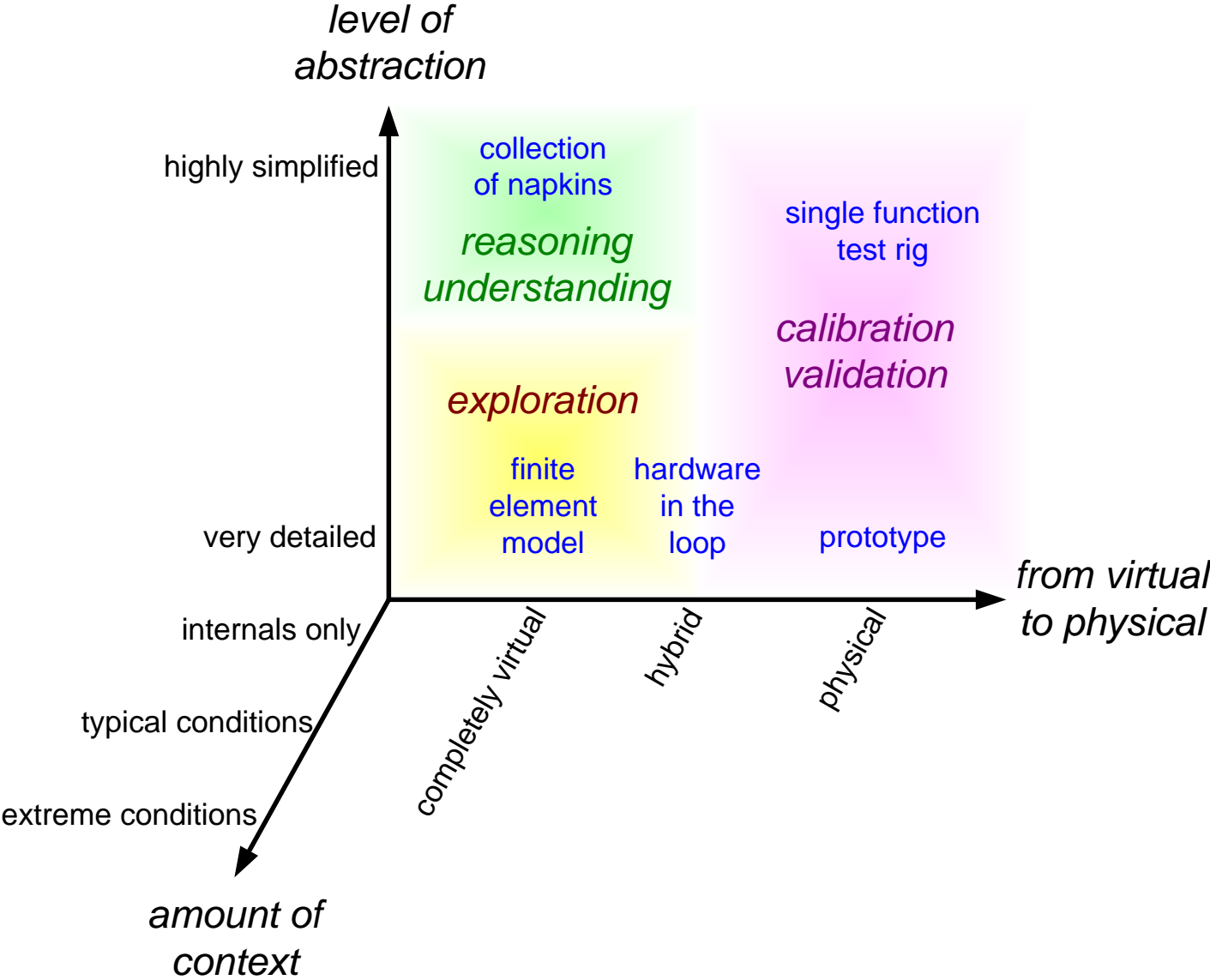
} generating, building, manufacturing, configuring, transporting,
installing, commissioning, diagnosing, analyzing, teaching, ...

test data and objects

environment physical conditions, physical and information infrastructure

people and their behavior

Modeling Space



Mastering Systems Integration; Project Management

by *Gerrit Muller* [TNO-ESI, University of South-Eastern Norway]

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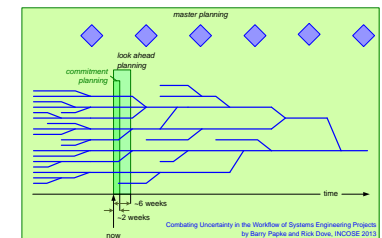
Abstract

Systems Integration requires specific project management. The challenge for project managers is to plan ahead, knowing that the integration plan will need continuous adaptations.

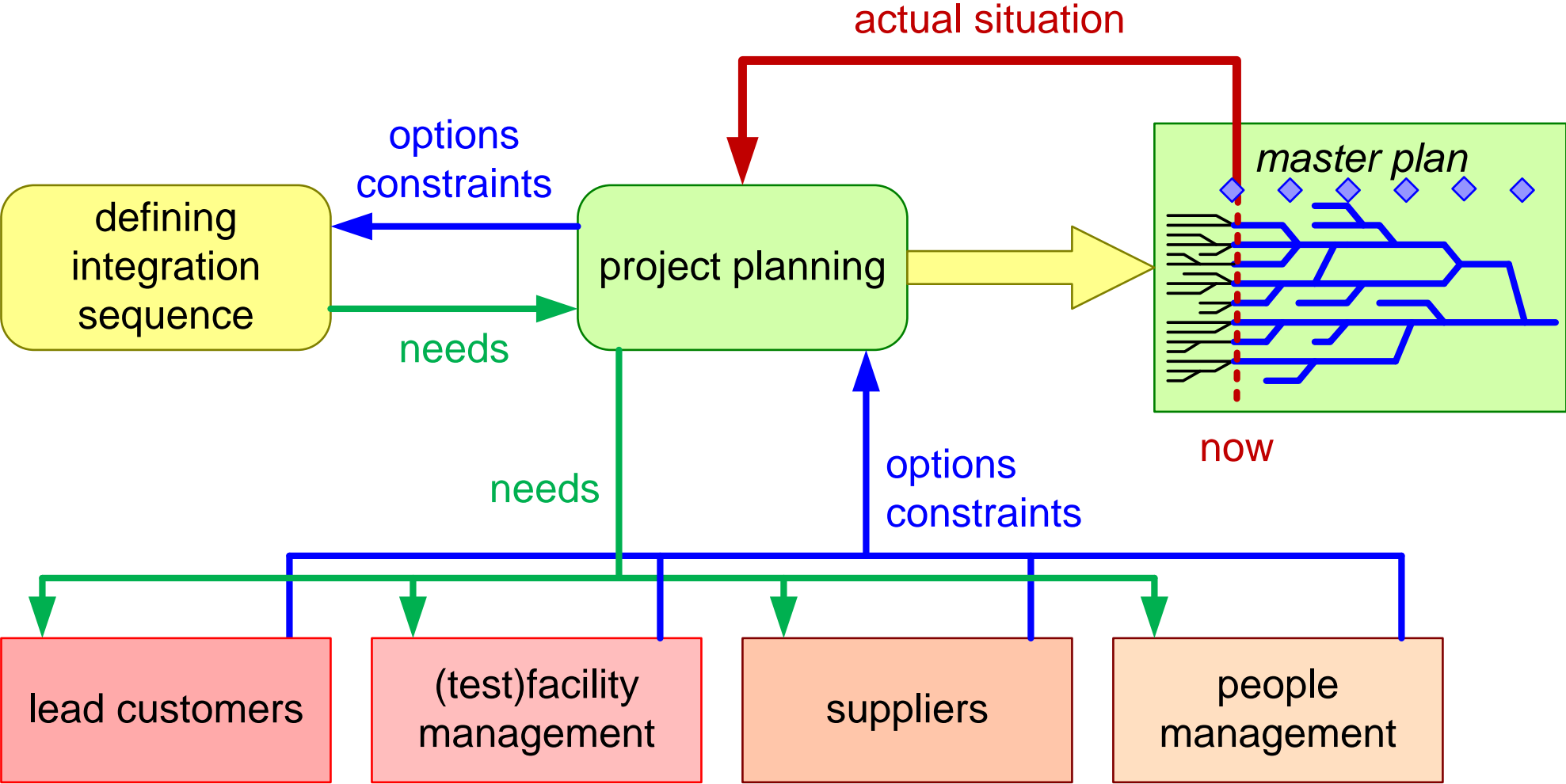
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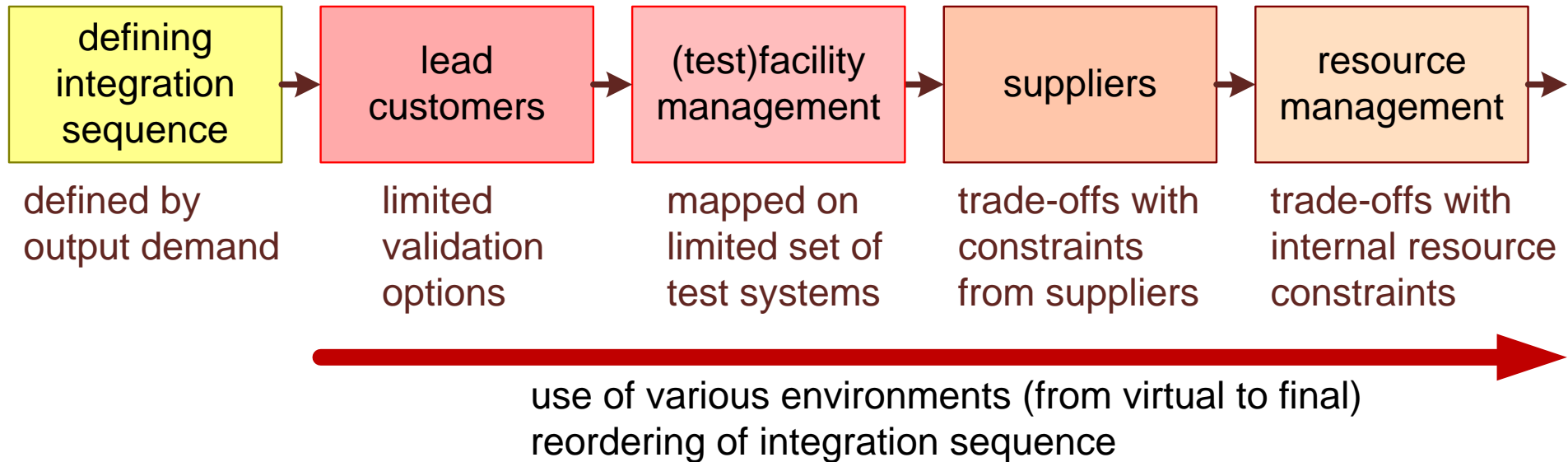
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version: 0.6



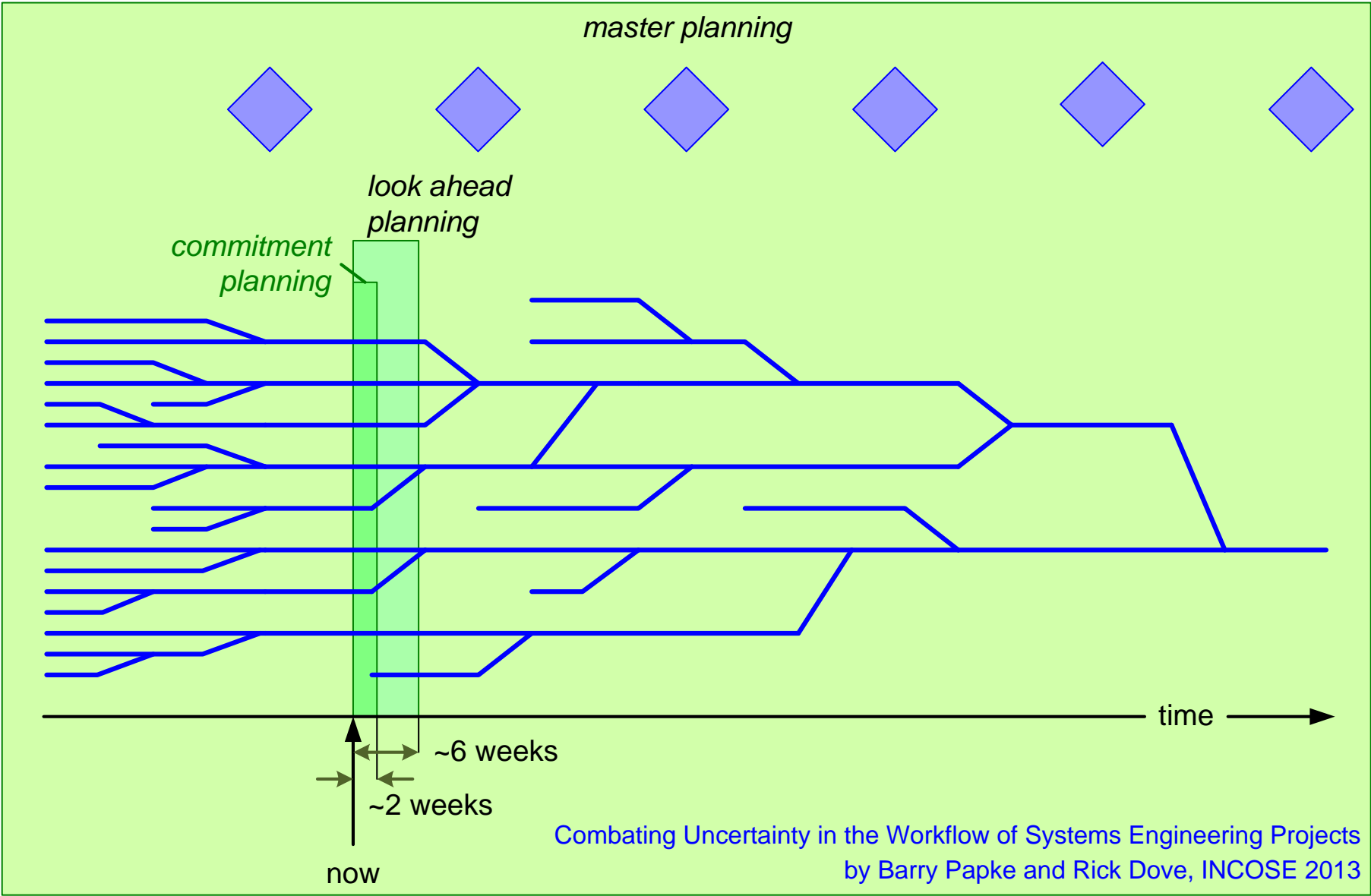
Integration Planning



Demand Driven, Fitting Constraints



Last Planner; Look Ahead!



Mastering Systems Integration; Process and Integration

by *Gerrit Muller* [TNO-ESI, University of South-Eastern Norway]

e-mail: `gaudisite@gmail.com`

`www.gaudisite.nl`

Abstract

This lesson discusses process aspects of systems integration, such as the organizational capabilities.

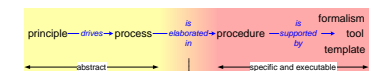
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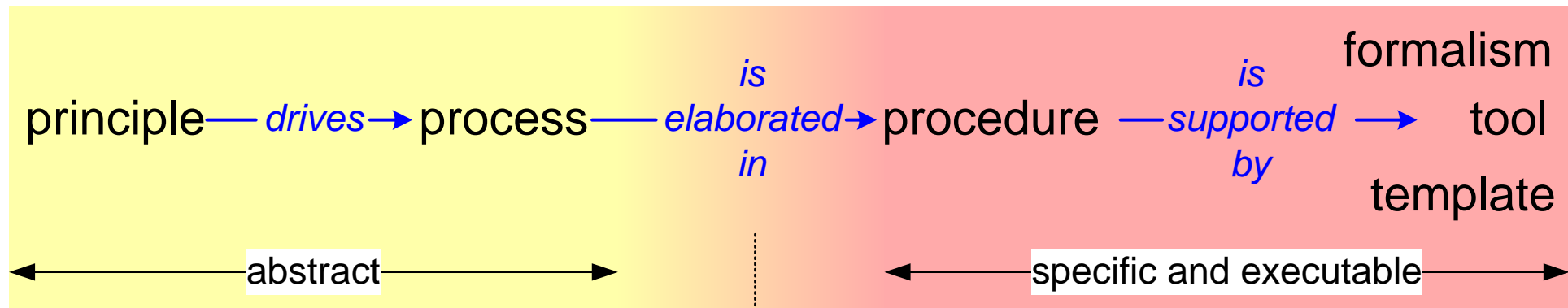
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version: 0



What is a Process?



Mastering Systems Integration; Organization

by *Gerrit Muller* [TNO-ESI, University of South-Eastern Norway]

e-mail: `gaudisite@gmail.com`

`www.gaudisite.nl`

Abstract

This presentation discusses organizational aspects, such as roles of people, of Systems Integration.

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logo
TBD

Roles in Systems Integration

project leader

organization
resources
schedule
budget

*systems architect/
engineer/integrator*
system requirements
design inputs
test specification
schedule rationale
troubleshooting
participate in test

system tester

test
troubleshooting
report

*logistics and
administrative support*
configuration
orders
administration

engineers
design
component test
troubleshooting
participate in test

machine owner

maintain test model
support test

Modeling and Analysis: Budgeting

by *Gerrit Muller* TNO-ESI, HSN-NISE

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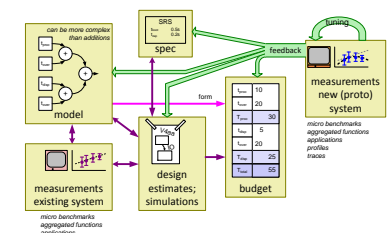
Abstract

This presentation addresses the fundamentals of budgeting: What is a budget, how to create and use a budget, what types of budgets are there. What is the relation with modeling and measuring.

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version: 1.0



content of this presentation

What and why of a budget

How to create a budget (decomposition, granularity, inputs)

How to use a budget

What is a Budget?

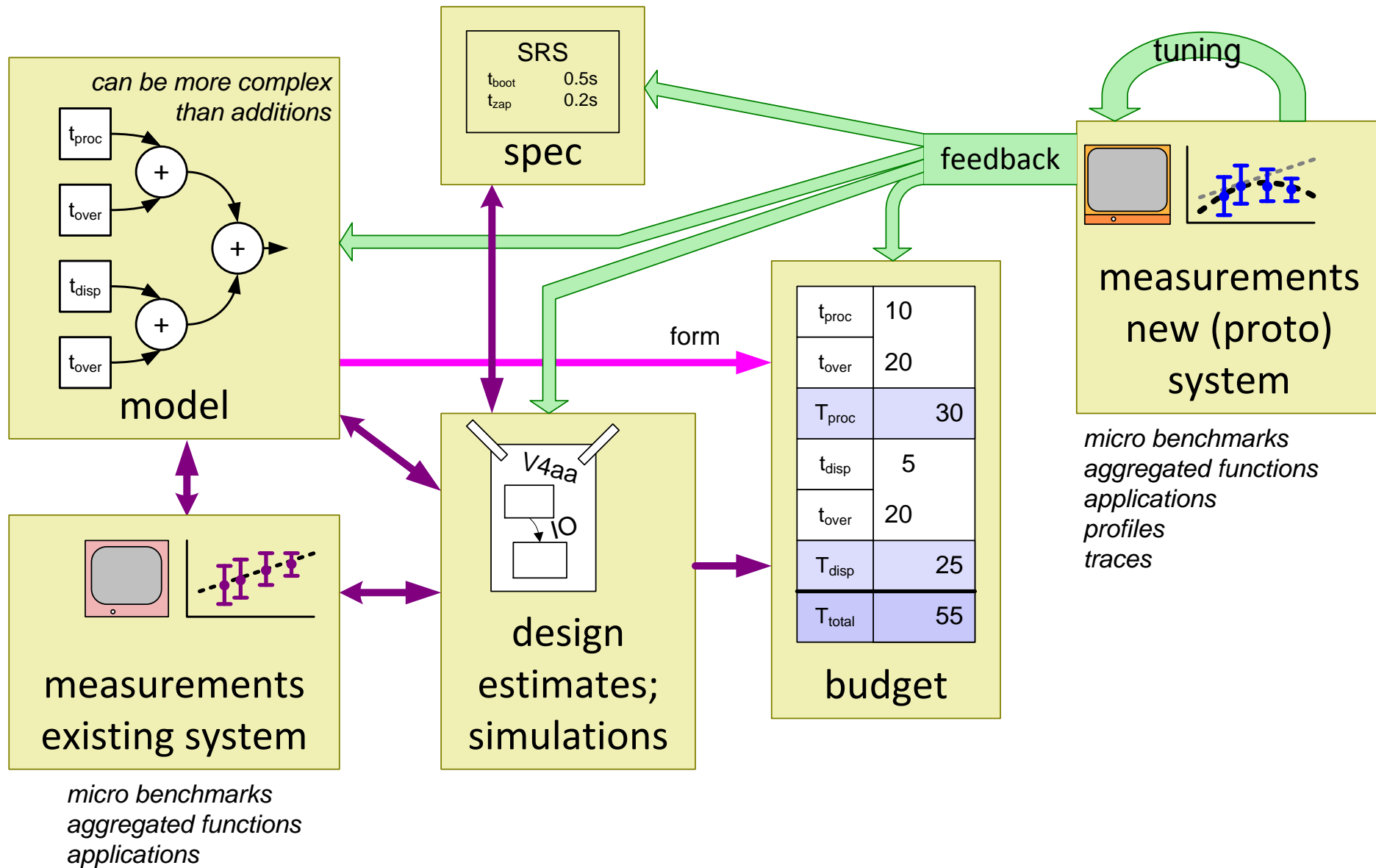
A **budget** is
a **quantified instantiation** of a **conceptual model**

A **budget** can
prescribe or **describe** the **contributions**
by **parts** of the **solution**
to the **system quality** under consideration

Why Budgets?

- to make the design explicit
- to provide a baseline to take decisions
- to specify the requirements for the detailed designs
- to have guidance during integration
- to provide a baseline for verification
- to manage the design margins explicitly

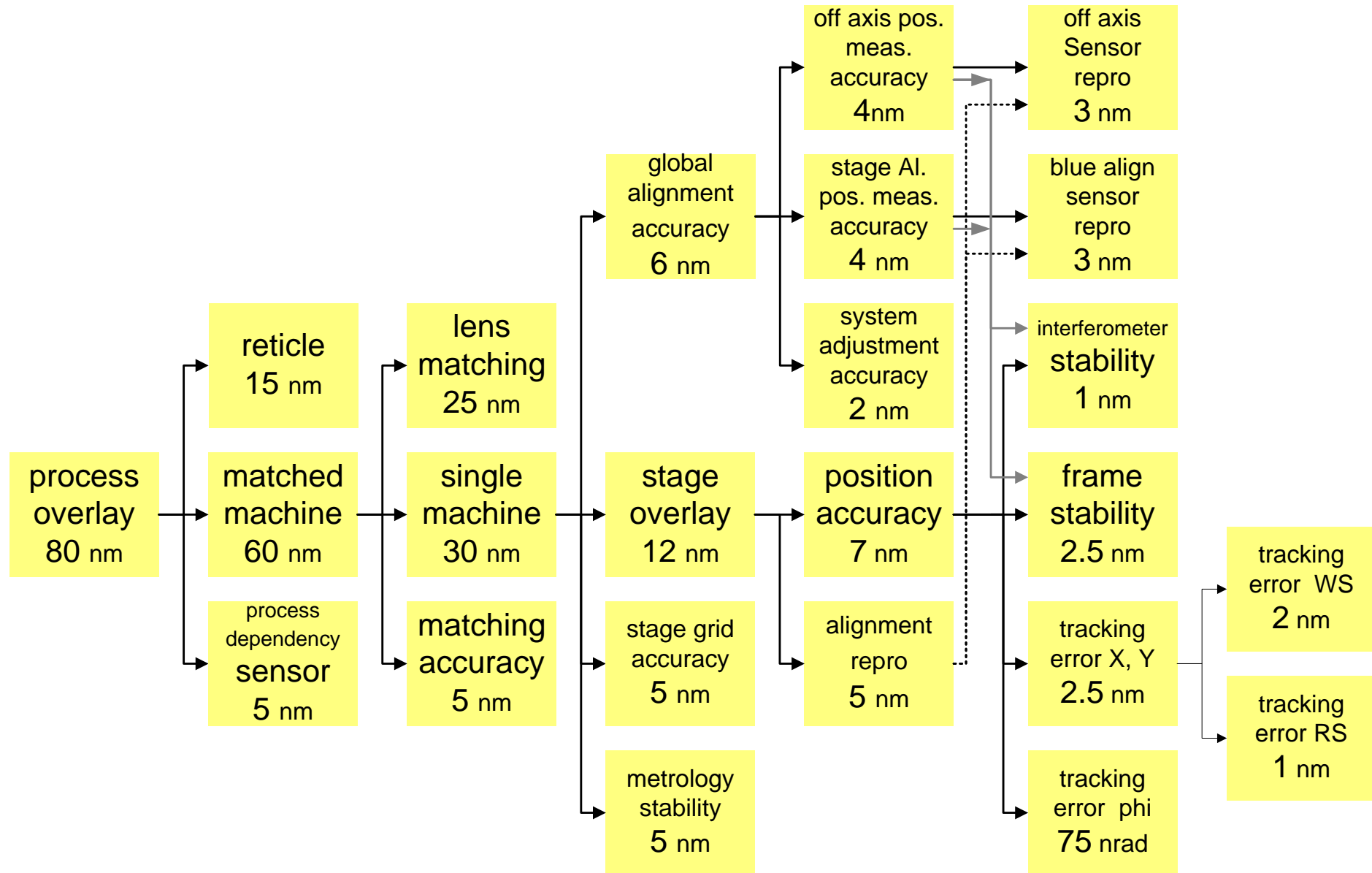
Visualization of Budget Based Design Flow



Stepwise Budget Based Design Flow

step	example
1A measure old systems	micro-benchmarks, aggregated functions, applications
1B model the performance starting with old systems	flow model and analytical model
1C determine requirements for new system	response time or throughput
2 make a design for the new system	explore design space, estimate and simulate
3 make a budget for the new system:	models provide the structure measurements and estimates provide initial numbers specification provides bottom line
4 measure prototypes and new system	micro-benchmarks, aggregated functions, applications profiles, traces
5 Iterate steps 1B to 4	

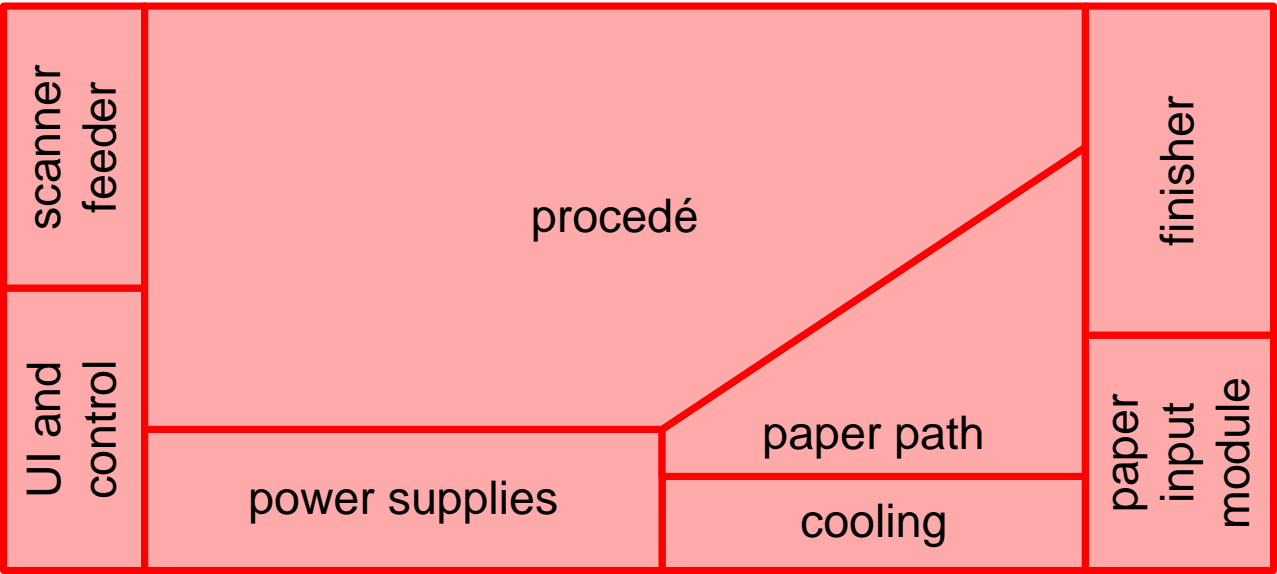
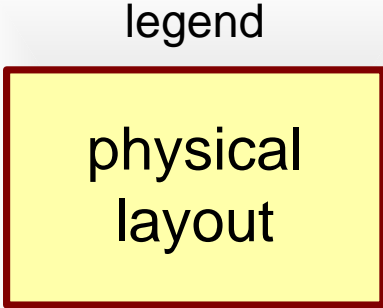
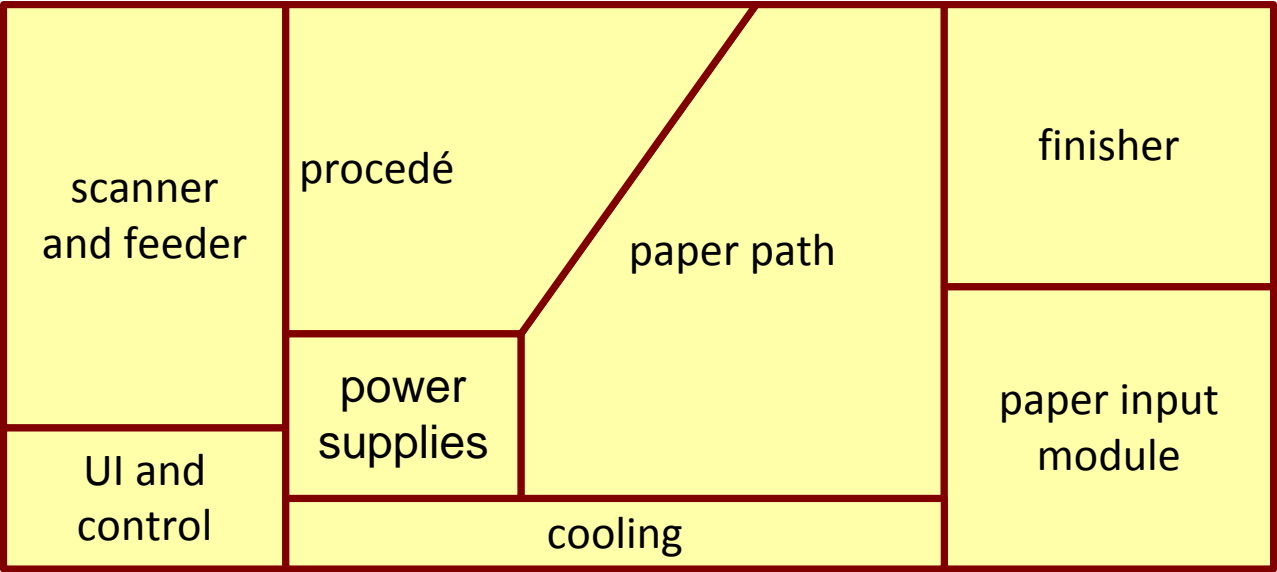
Budgets Applied on Waferstepper Overlay



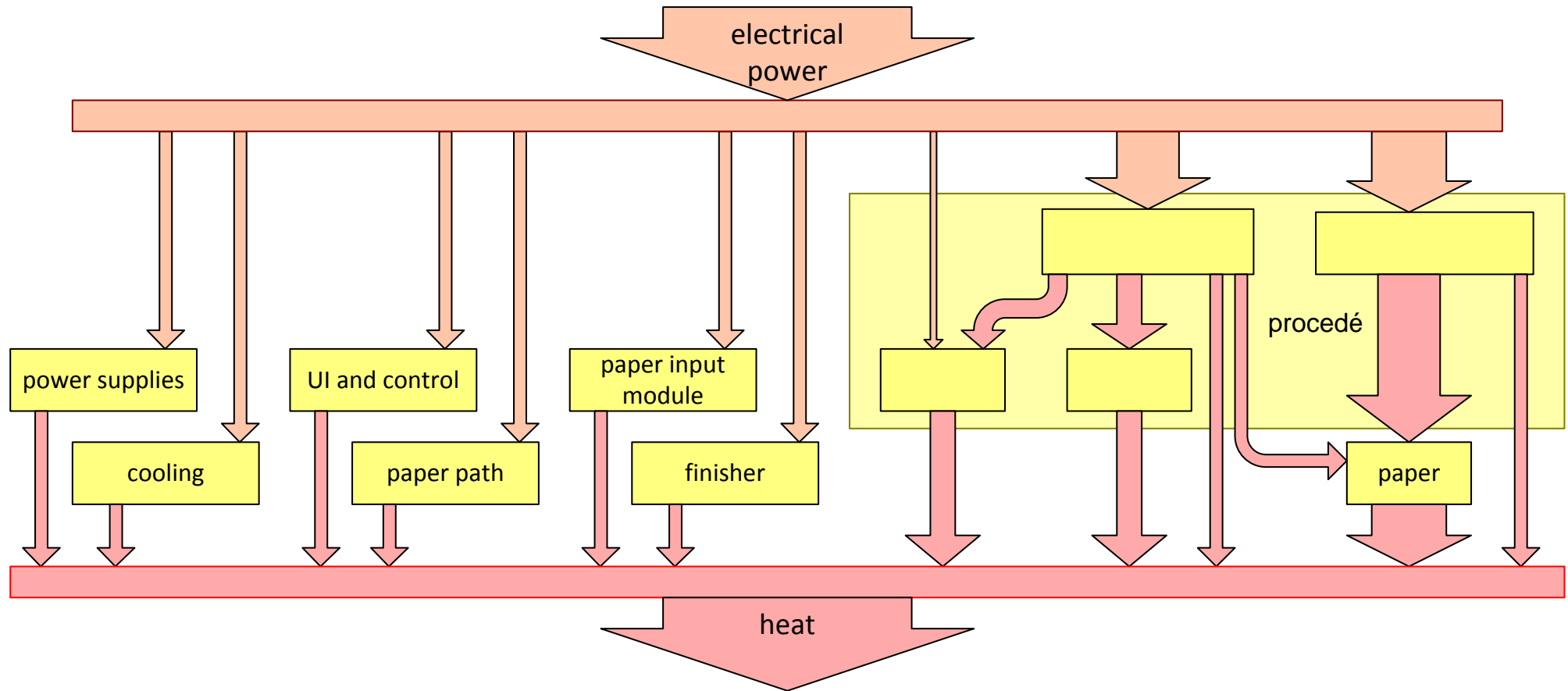
Budgets Applied on Medical Workstation Memory Use

<i>memory budget in Mbytes</i>	code	obj data	bulk data	total
shared code	11.0			11.0
User Interface process	0.3	3.0	12.0	15.3
database server	0.3	3.2	3.0	6.5
print server	0.3	1.2	9.0	10.5
optical storage server	0.3	2.0	1.0	3.3
communication server	0.3	2.0	4.0	6.3
UNIX commands	0.3	0.2	0	0.5
compute server	0.3	0.5	6.0	6.8
system monitor	0.3	0.5	0	0.8
application SW total	13.4	12.6	35.0	61.0
UNIX Solaris 2.x				10.0
file cache				3.0
total				74.0

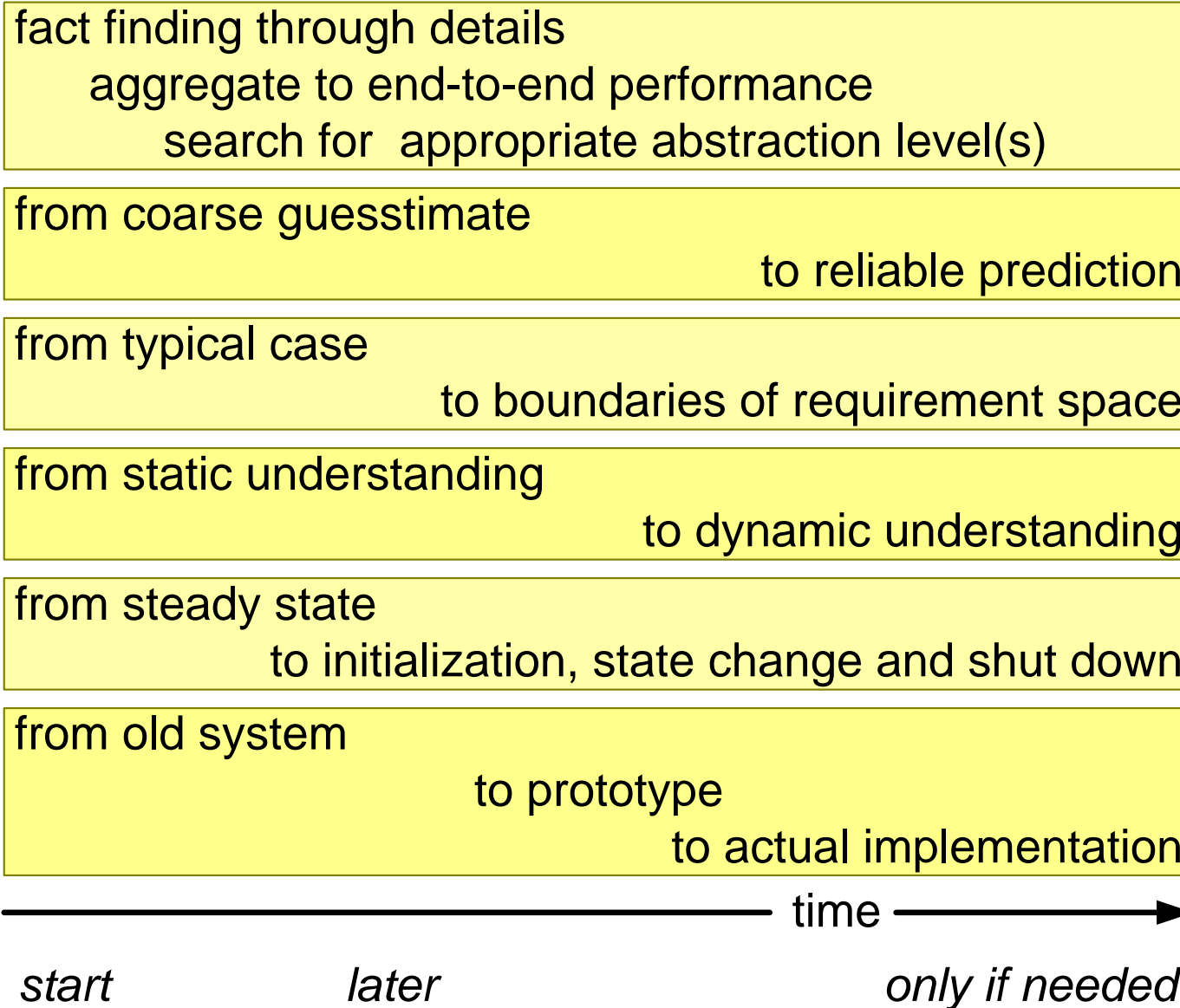
Power Budget Visualization for Document Handler



Alternative Power Visualization



Evolution of Budget over Time



Potential Applications of Budget based design

- resource use (CPU, memory, disk, bus, network)
- timing (response, latency, start up, shutdown)
- productivity (throughput, reliability)
- Image Quality parameters (contrast, SNR, deformation, overlay, DOF)
- cost, space, time

What kind of budget is required?

static	dynamic
typical case	worst case
global	detailed
approximate	accurate

is the budget based on wish, empirical data, extrapolation, educated guess, or expectation?

Summary of Budgeting

A budget is a quantified instantiation of a model

A budget can prescribe or describe the contributions by parts of the solution to the system quality under consideration

A budget uses a decomposition in tens of elements

The numbers are based on historic data, user needs, first principles and measurements

Budgets are based on models and estimations

Budget visualization is critical for communication

Budgeting requires an incremental process

Many types of budgets can be made; start simple!

The Boderc project contributed to Budget Based Design. Especially the work of *Hennie Freriks, Peter van den Bosch (Océ), Heico Sandee and Maurice Heemels (TU/e, ESI)* has been valuable.

Mastering Systems Integration; Testing

by *Gerrit Muller* [TNO-ESI, University of South-Eastern Norway]

e-mail: `gaudisite@gmail.com`

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Abstract

During integration, the integrators continuously test parts, functions, and systems. Testing requires the creation of an experimental set-up, where the test environment offers stimuli and measures responses. This lesson discusses some of the testing methods and considerations.

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Why Testing?

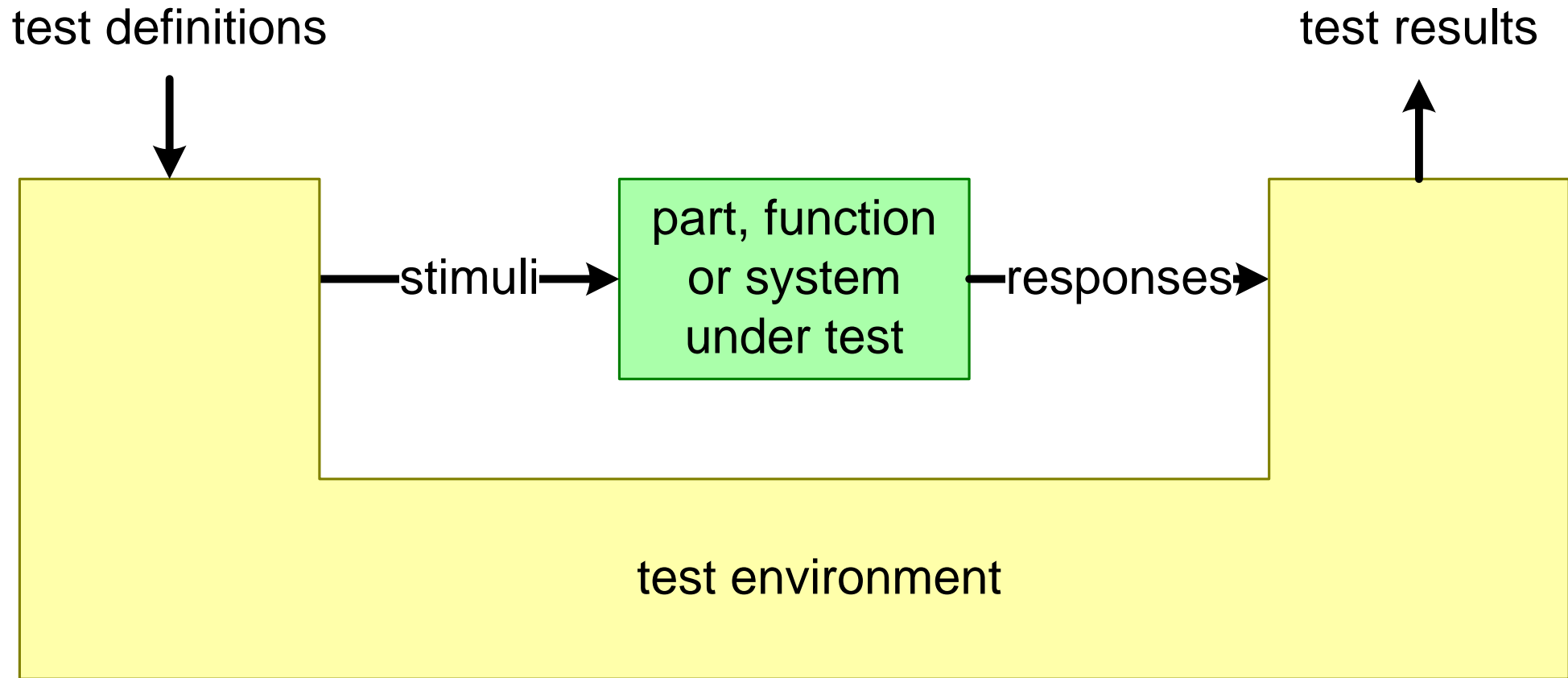
Objectives of testing during integration:

- to find potential quality attribute and behavior problems at specification and design level as early as possible.
- to learn as much as possible about the emerging quality attributes and behaviors.

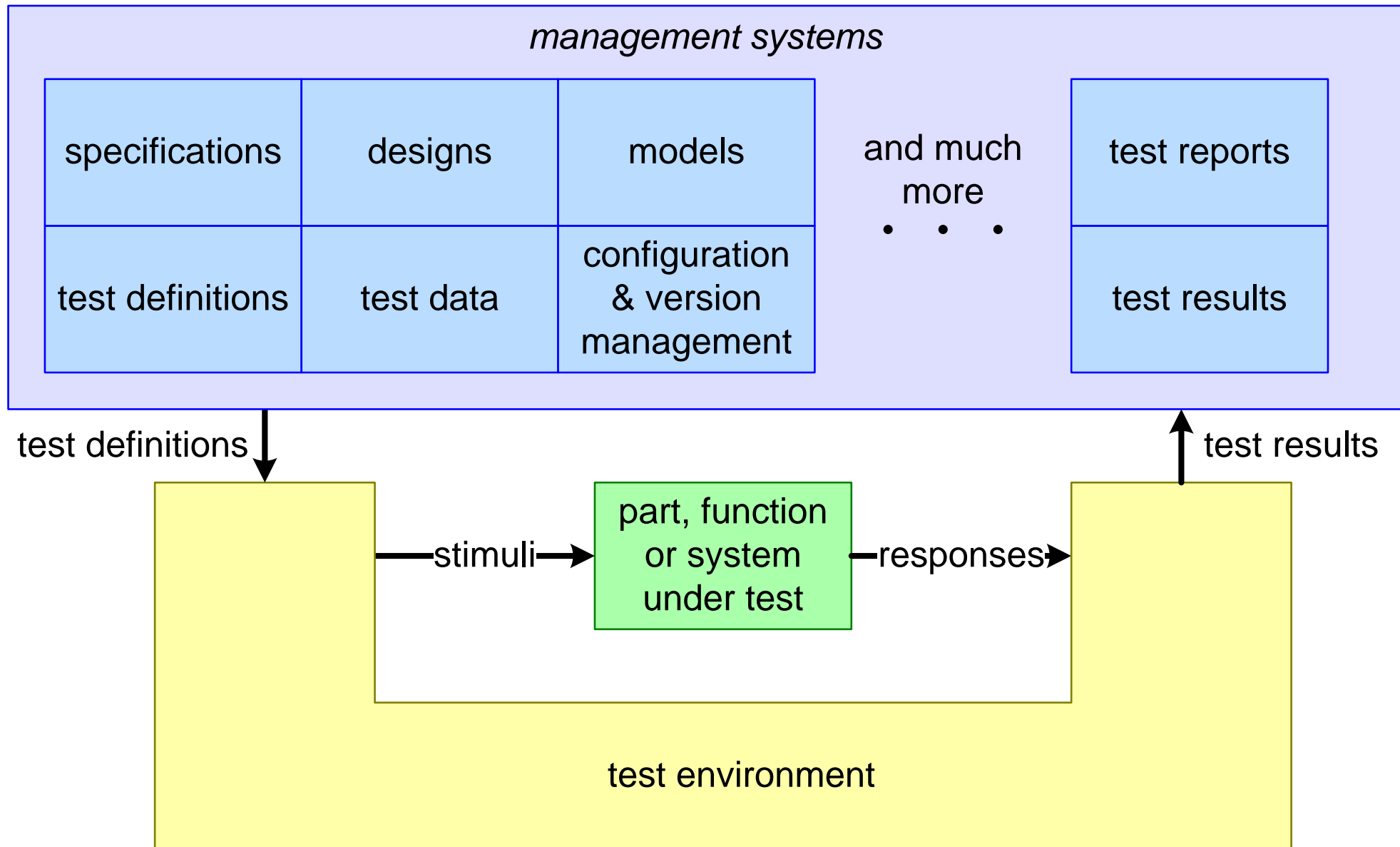
Consequences for testing:

- stimulate the object under test externally and internally (insertion)
- observe the system externally (specification) and internally (design)

Testing Environment



Testing Environment Management Systems Context



Accelerated Testing

During normal use, stimuli are periodic, with frequencies f_0 , f_1 , f_2 , etc.

During accelerated testing these frequencies are increased.

- **ALT** (Accelerated Life Testing) is **Test-to-Pass** (showing how long the system can operate)
- **HALT** (Highly Accelerated Life Testing) is **Test-to-Fail** (learning weaknesses and margins)

The concepts are applicable in hardware, software, and systems. However, engineers know the stimuli for hardware better (temperature, humidity, vibrations, etc.).

Mastering Systems Integration; Readiness Levels

by *Gerrit Muller* [TNO-ESI, University of South-Eastern Norway]

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Abstract

Readiness level models offer a yardstick to assess the status of specific project aspects. Examples are technology readiness and integration readiness.

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Technology Readiness Levels

TRL 9	actual system proven in operational environment
TRL 8	system complete and qualified
TRL 7	system prototype demonstration in operational environment
TRL 6	technology demonstrated in relevant environment
TRL 5	technology validated in relevant environment
TRL 4	technology validated in lab
TRL 3	experimental proof of concept
TRL 2	technology concept formulated
TRL 1	basic principles observed

after: <https://serkanbolat.com/2014/11/03/technology-readiness-level-trl-math-for-innovative-smes/>

Integration Readiness Levels

TRL 7	The integration of technologies has been verified and validated with sufficient detail to be actionable.
TRL 6	The integrating technologies can accept, translate, and structure information for its intended application.
TRL 5	There is sufficient control between technologies necessary to establish, manage, and terminate the integration.
TRL 4	There is sufficient detail in the quality and assurance of the integration between technologies.
TRL 3	There is compatibility (i.e. common language) between technologies to orderly and efficiently integrate and interact.
TRL 2	There is some level of specificity to characterize the interaction (i.e. ability to influence) between technologies through their interface.
TRL 1	An interface (i.e. physical connection) between technologies has been identified with sufficient detail to allow characterization of the relationship.

from: From TRL to SRL: The Concept of Systems Readiness Levels, CSER2006, by Sauser et al.

Mastering Systems Integration; Systems of Systems

by *Gerrit Muller* [TNO-ESI, University of South-Eastern Norway]

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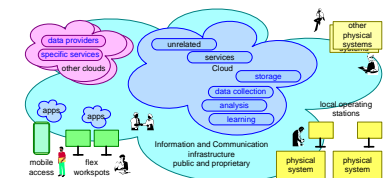
Abstract

Most end-user functionality and services are realized by Systems of Systems. Many of these systems may include organizations and humans; the systems aren't technical artifacts anymore. These systems evolve over time individually and typically lack a centralized governance. The resulting end-to-end qualities depend on all constituent systems and their interoperability.

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Types of Systems of Systems

Directed - The SoS is centrally managed

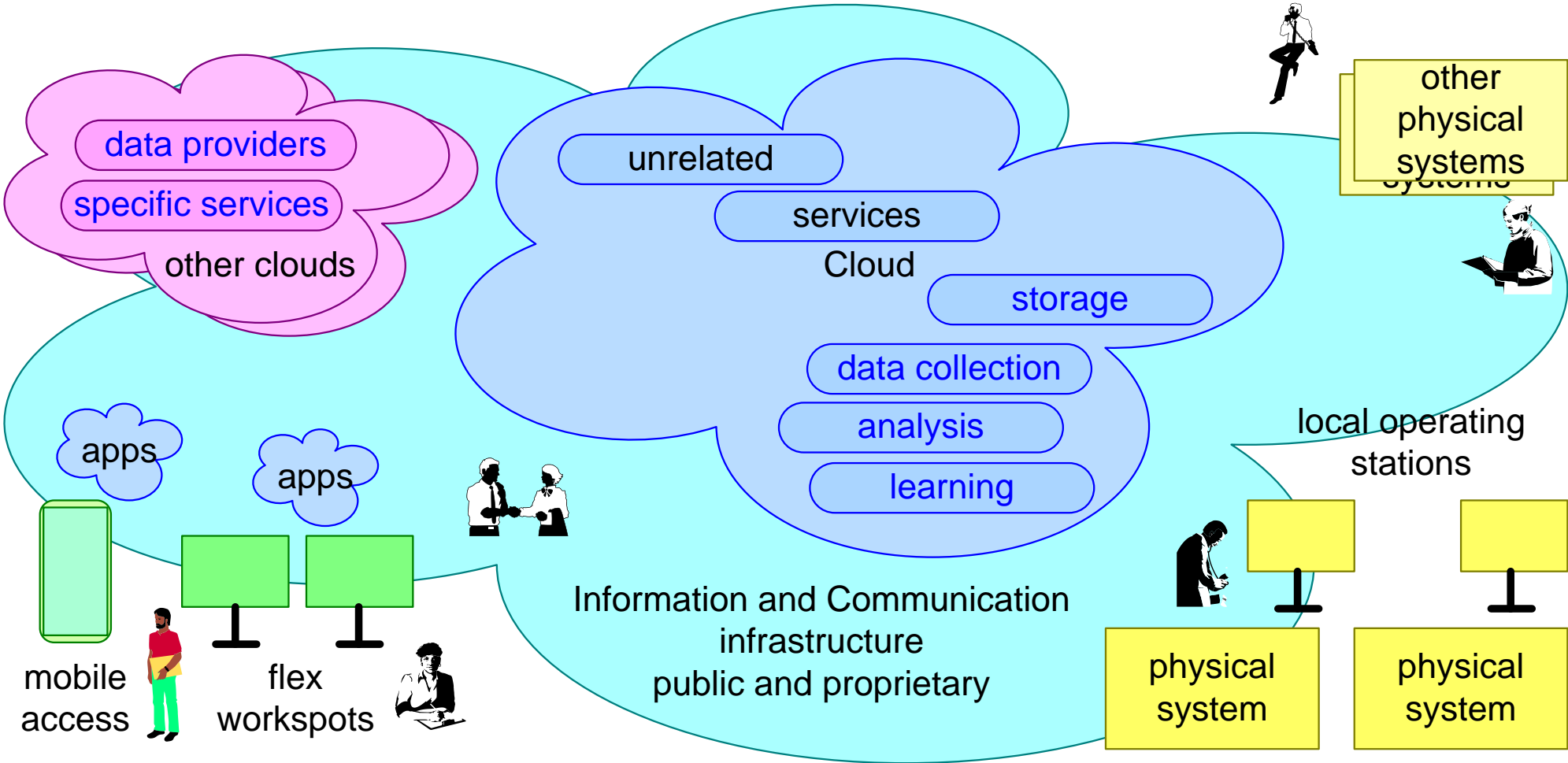
Acknowledged - The SoS has recognized objectives, and active cooperation between SoS and constituent systems

Collaborative - The constituent systems and stakeholders cooperate

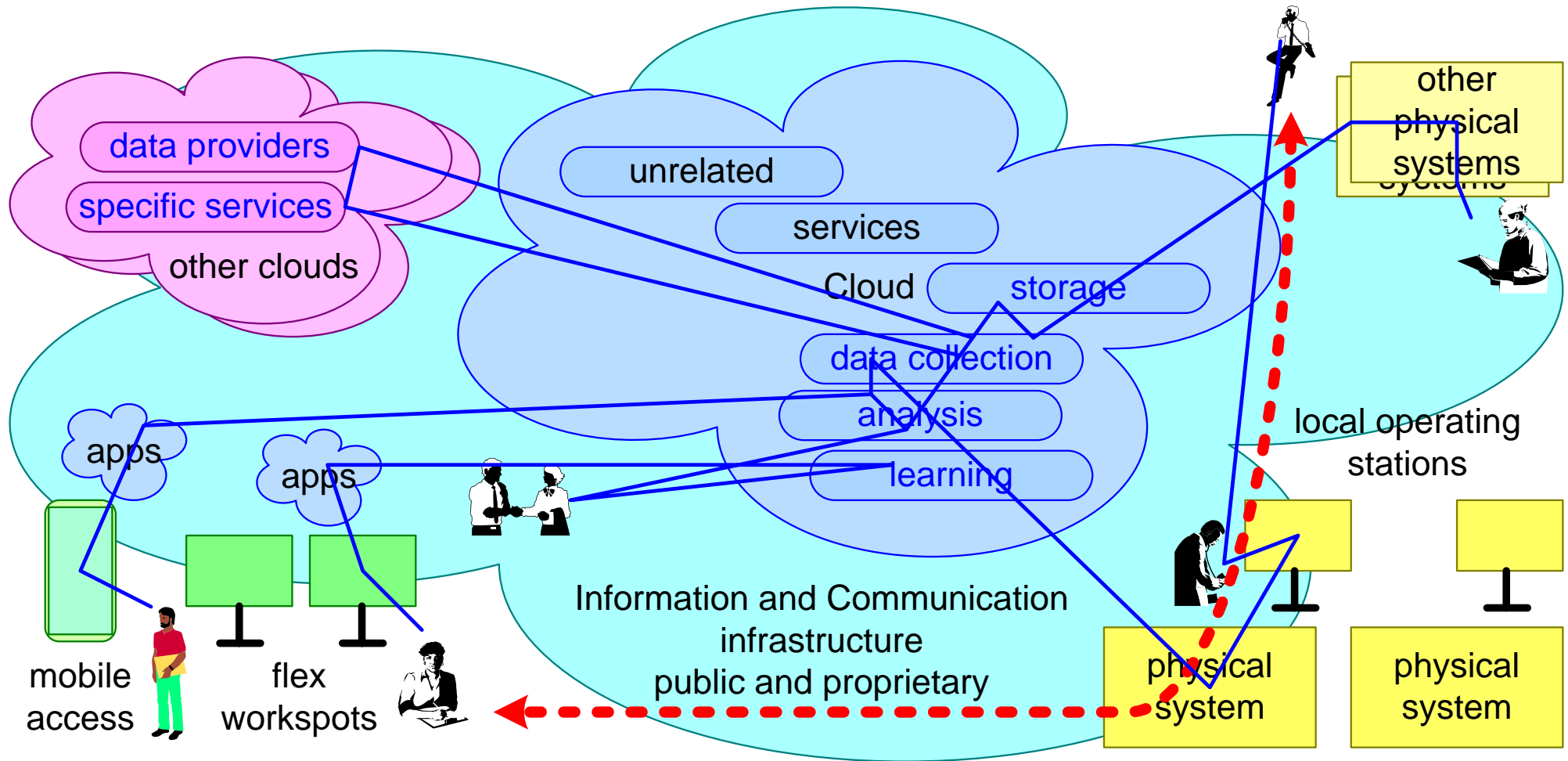
Virtual - The SoS nature more or less emerge from the constituent systems

J. Dahmann and K. Baldwin. 2008. "Understanding the Current State of US Defense Systems of Systems and the Implications for Systems Engineering." IEEE Systems Conference 2008 in Montreal, 2008

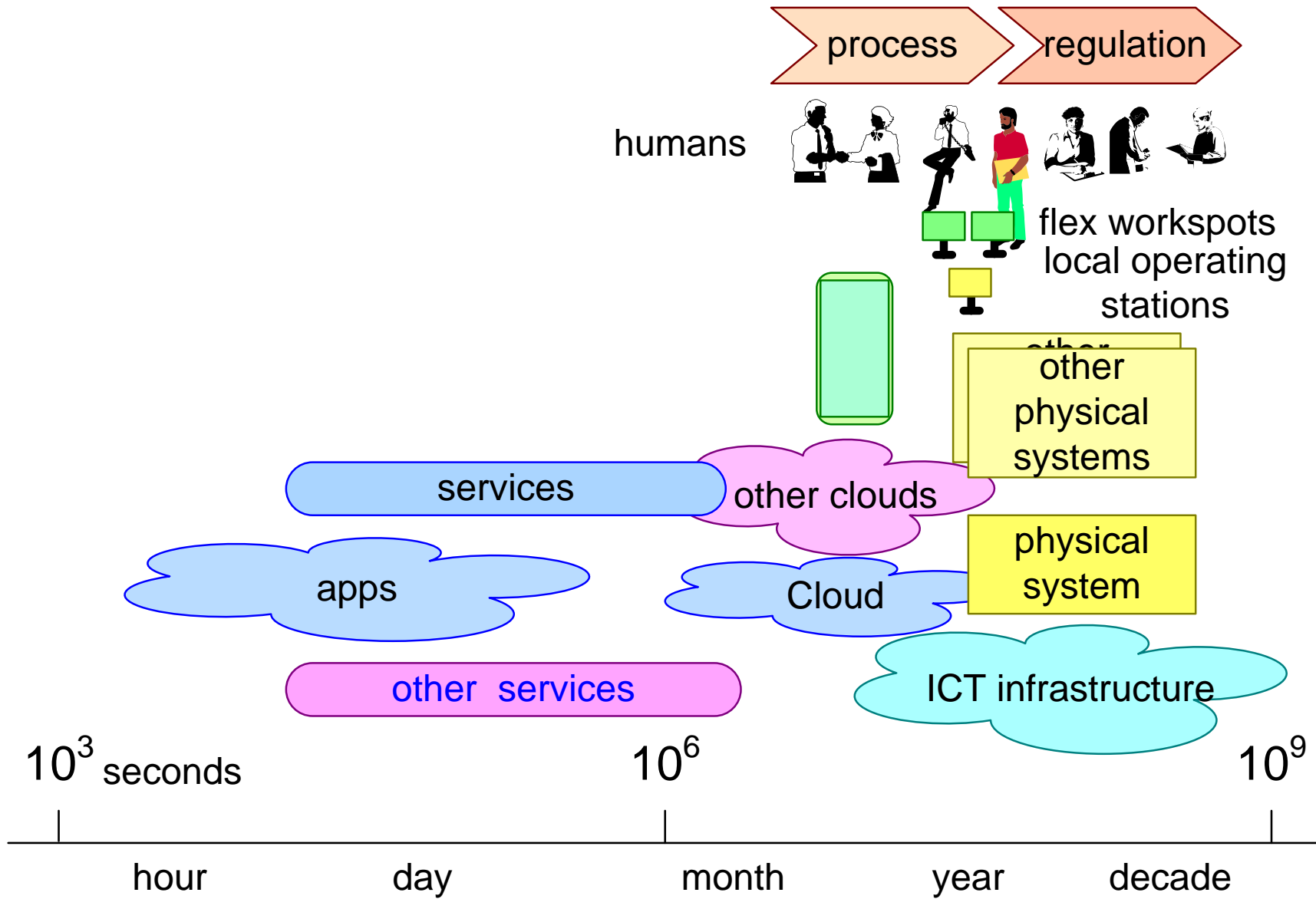
Where are the System Boundaries?



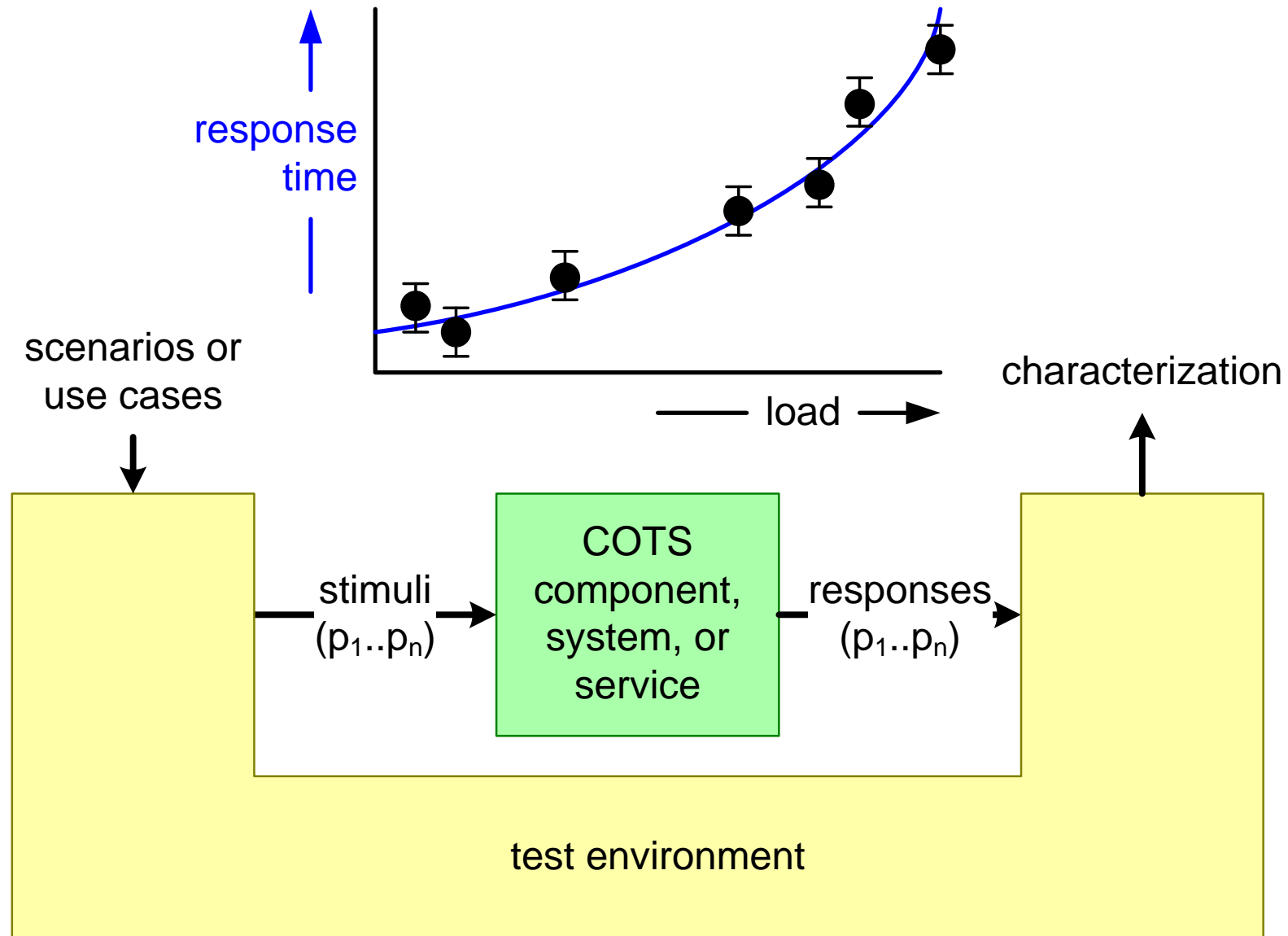
End-to-End Function



Varying Dynamics



Characterization of Black Box Parts



Summary

- Systems of Systems Integration **continues in the field** during operation
- **Ownership** and **responsibility** for end-to-end performance is **ill-defined**
- **Your system** may be **blamed** for problems with a **root cause elsewhere**
- End-to-end performance depends on a mix of
 - traditional **technical** systems
 - **modern technologies** like learning
 - **humans** in their organizational and societal context (psychological, social, political, economical, legal, etc.)
 - the **physical** context (location, climate, etc.) and laws of physics

Keywords from various SoS models in literature

Boardman and Sauser	Maier	DeLaurentis	Dahmann and Baldwin
Autonomy	Operational independence	Type	Directed
Belonging	Managerial independence	Control (or autonomy)	Acknowledged
Connectivity	Geographic separation	Connectivity	Collaborative
Diversity	Emergent behavior		Virtual
Emergence	Evolutionary development		

Mastering Systems Integration; Impact of Change

by *Gerrit Muller* [TNO-ESI, University of South-Eastern Norway]

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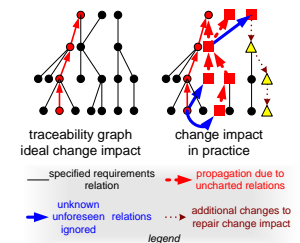
Abstract

This presentation explains the impact of change. A frequent problem is that people do not foresee the impact of changes they make to the system. A naive assumption is that traceability or dependency graphs will show them such impact. Reality then hits them during systems integration.

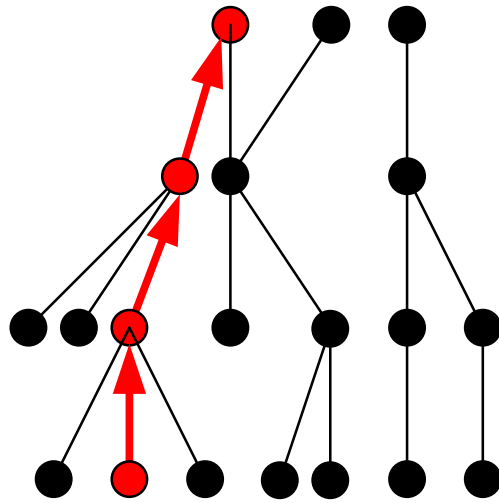
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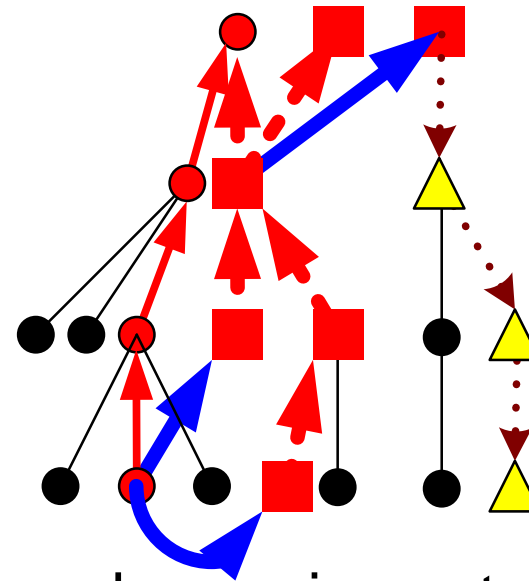
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version: 0



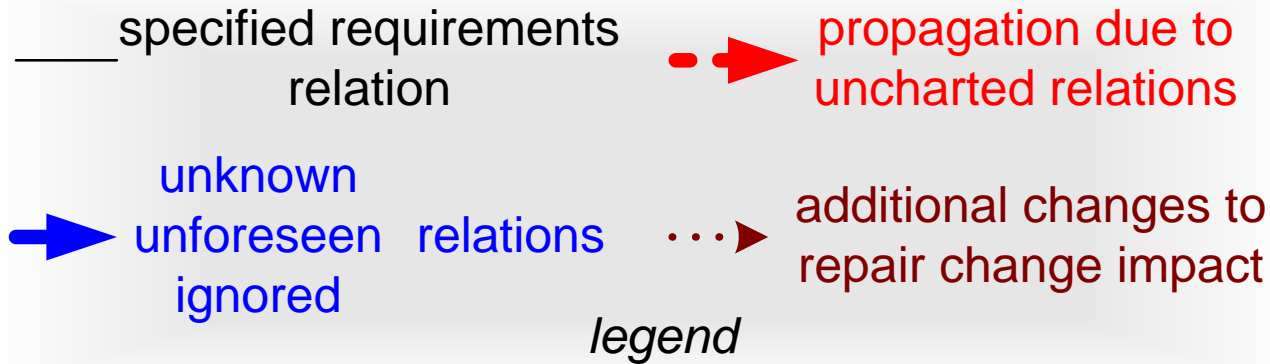
Impact of Change due to Unforeseens



traceability graph
ideal change impact

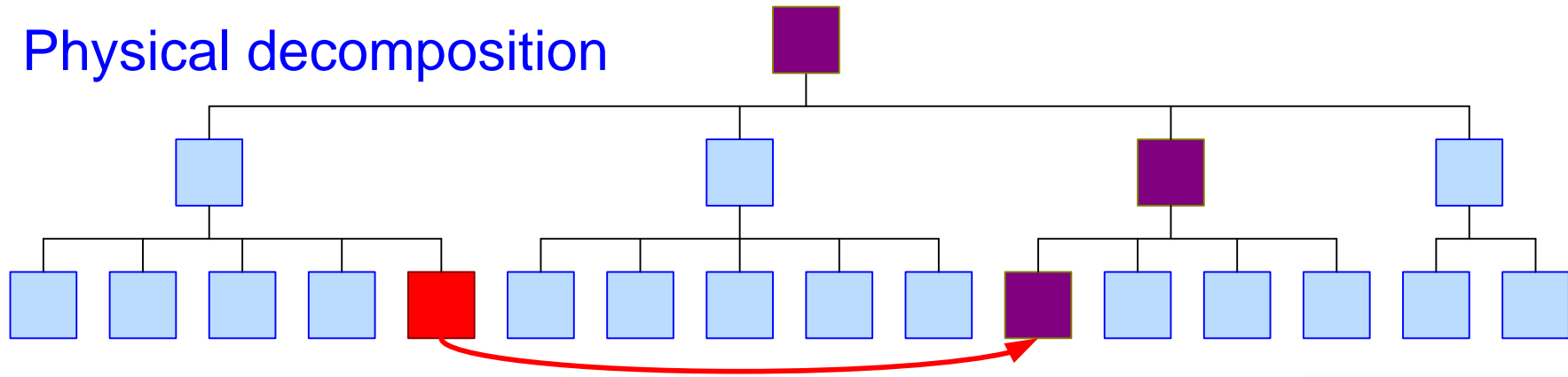


change impact
in practice



Root Cause is Often Elsewhere

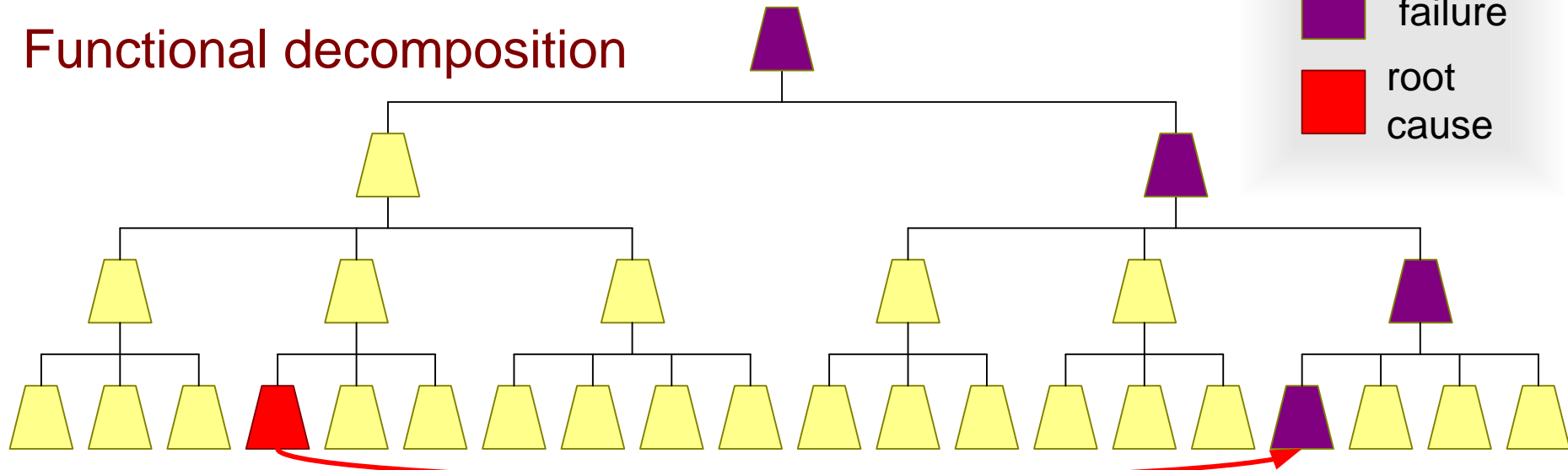
Physical decomposition



legend

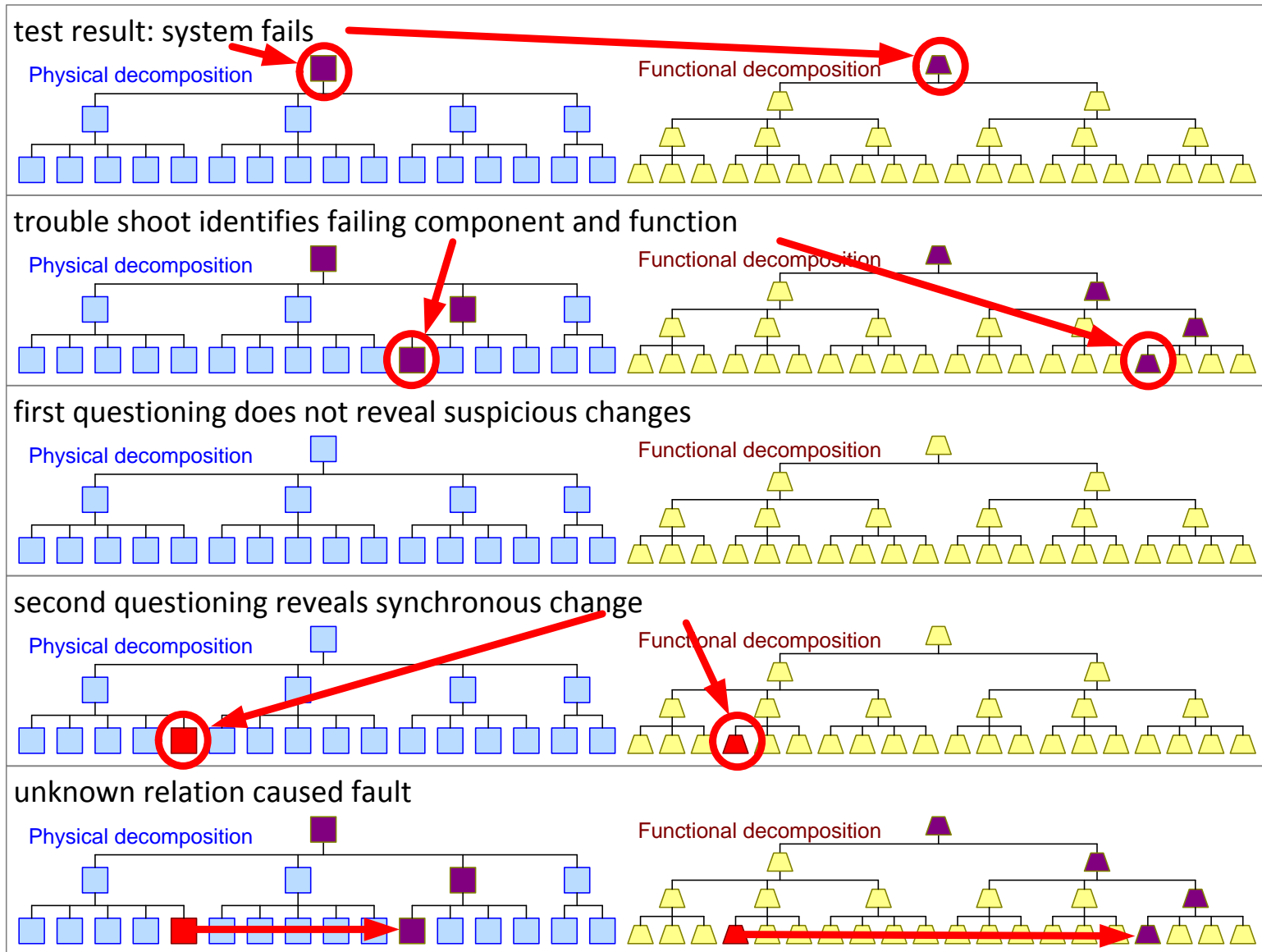
- failure
- root cause

Functional decomposition



unknown or unexpected relation

“Nothing has been changed...”



Mastering Systems Integration; Software and Integration

by *Gerrit Muller* [TNO-ESI, University of South-Eastern Norway]

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Abstract

Software has a number of characteristics, which impact systems integration.

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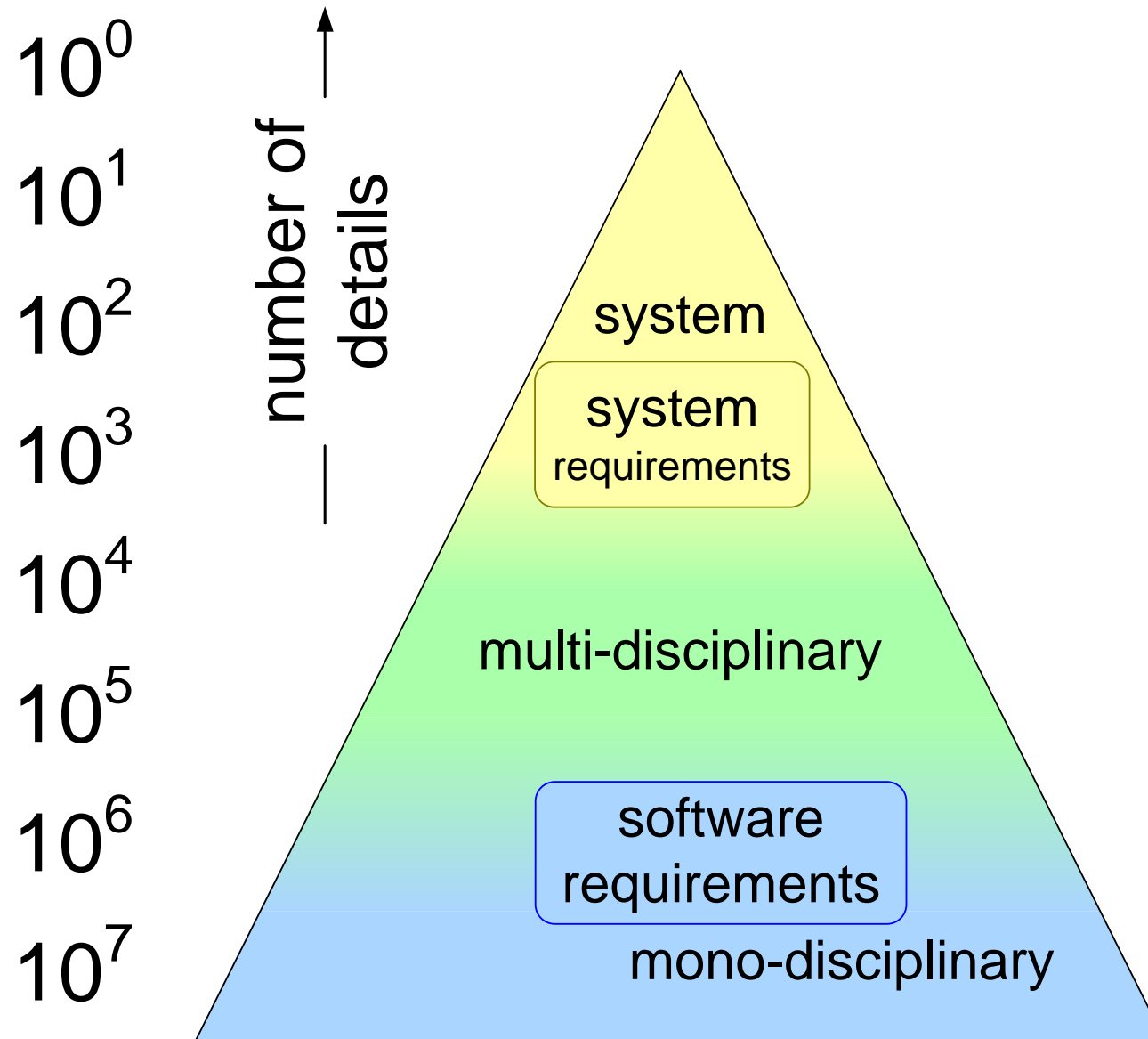
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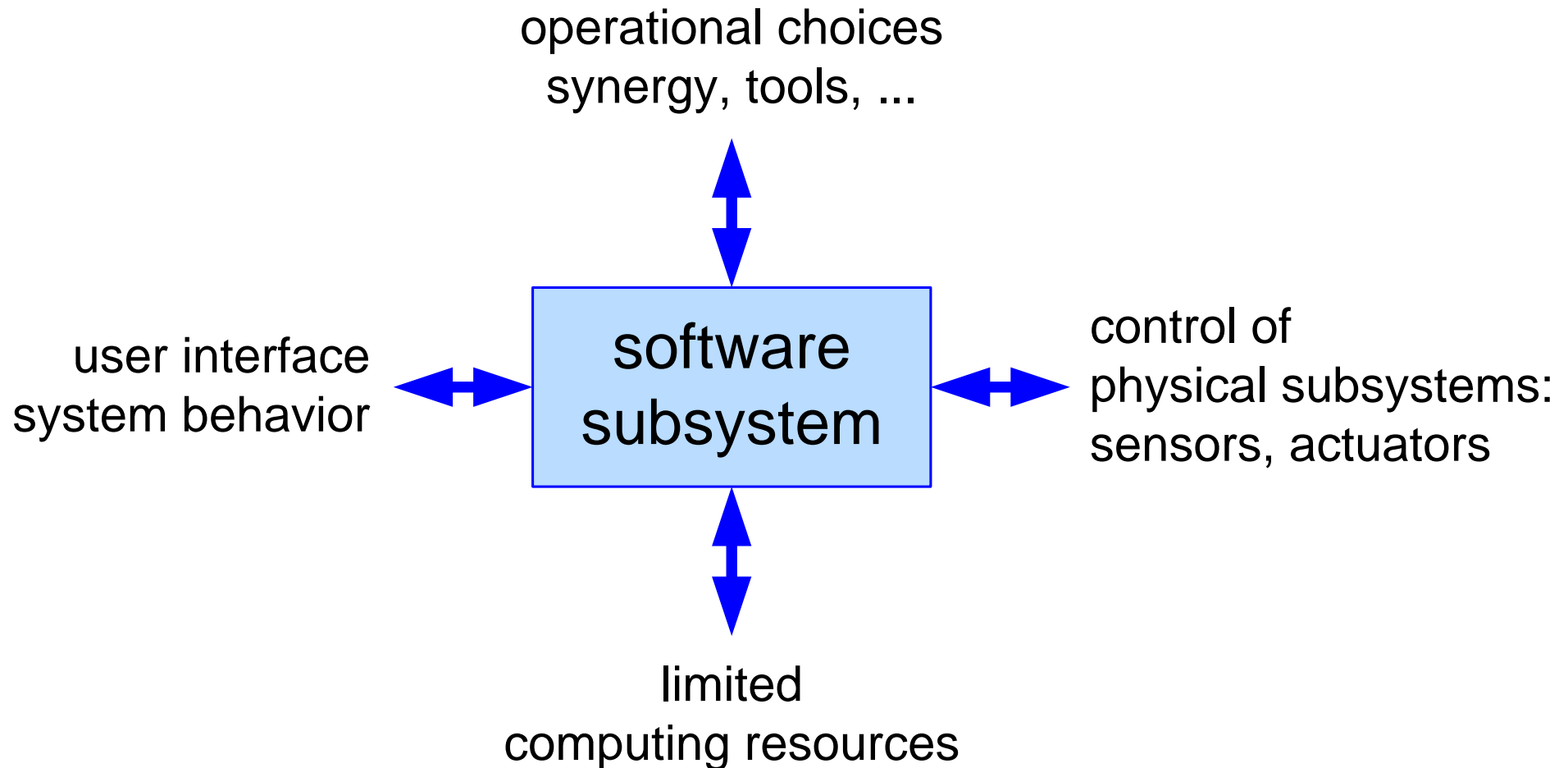
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TBD

When SW engineers demand "requirements",
then they expect *frozen* inputs
to be used for
the design, implementation and validation
of the software

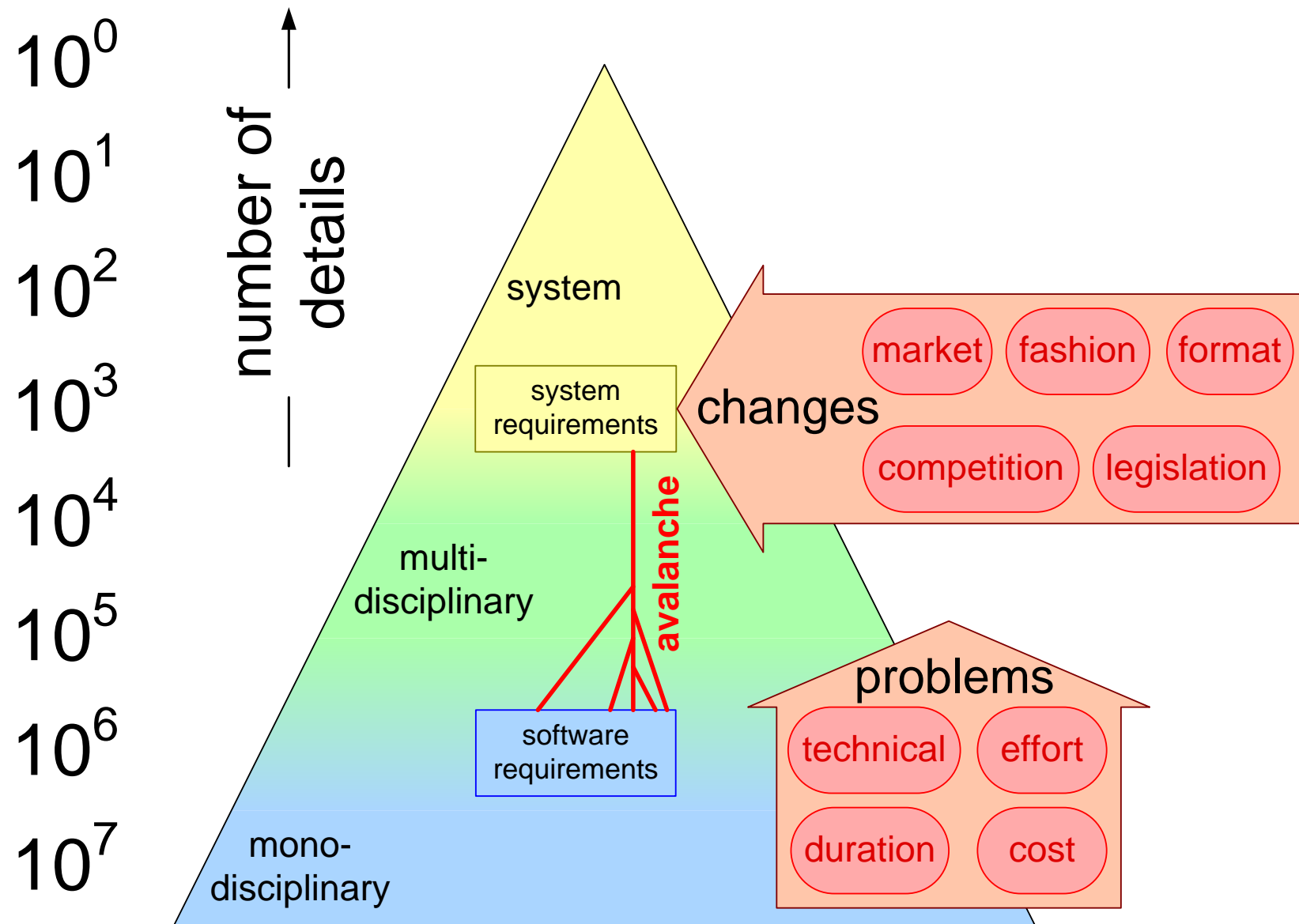
System vs Software Requirements



Why is the Software Requirement Specification so Large?

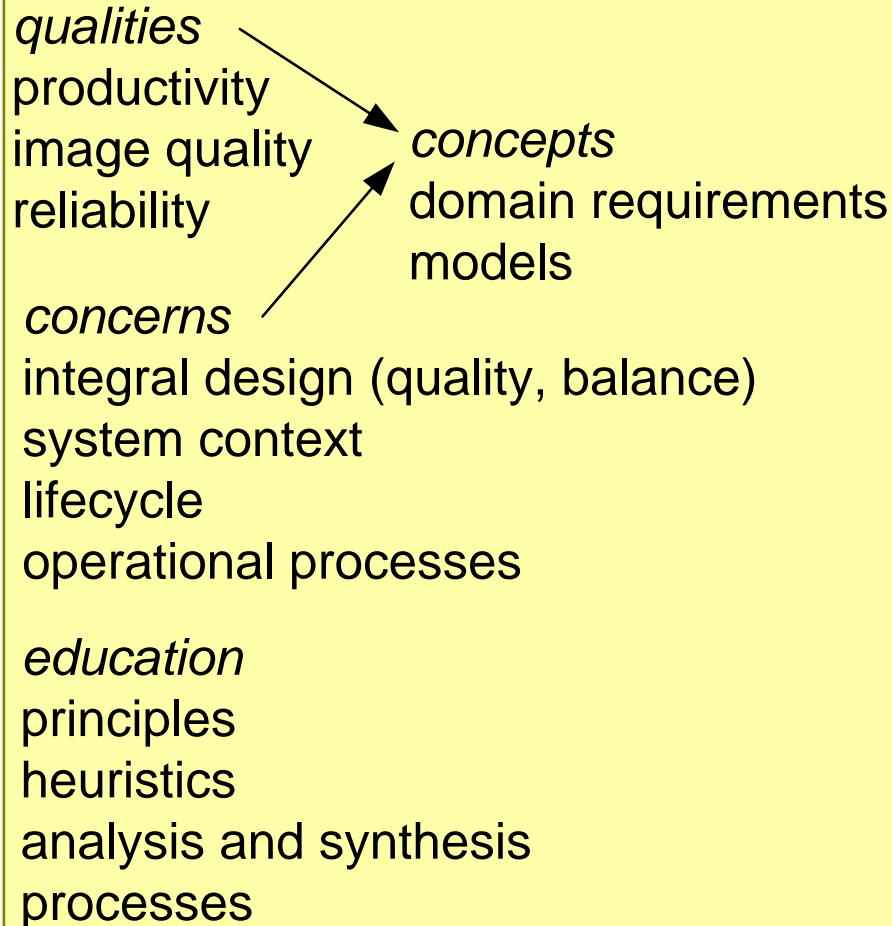


And why is it never up-to-date?

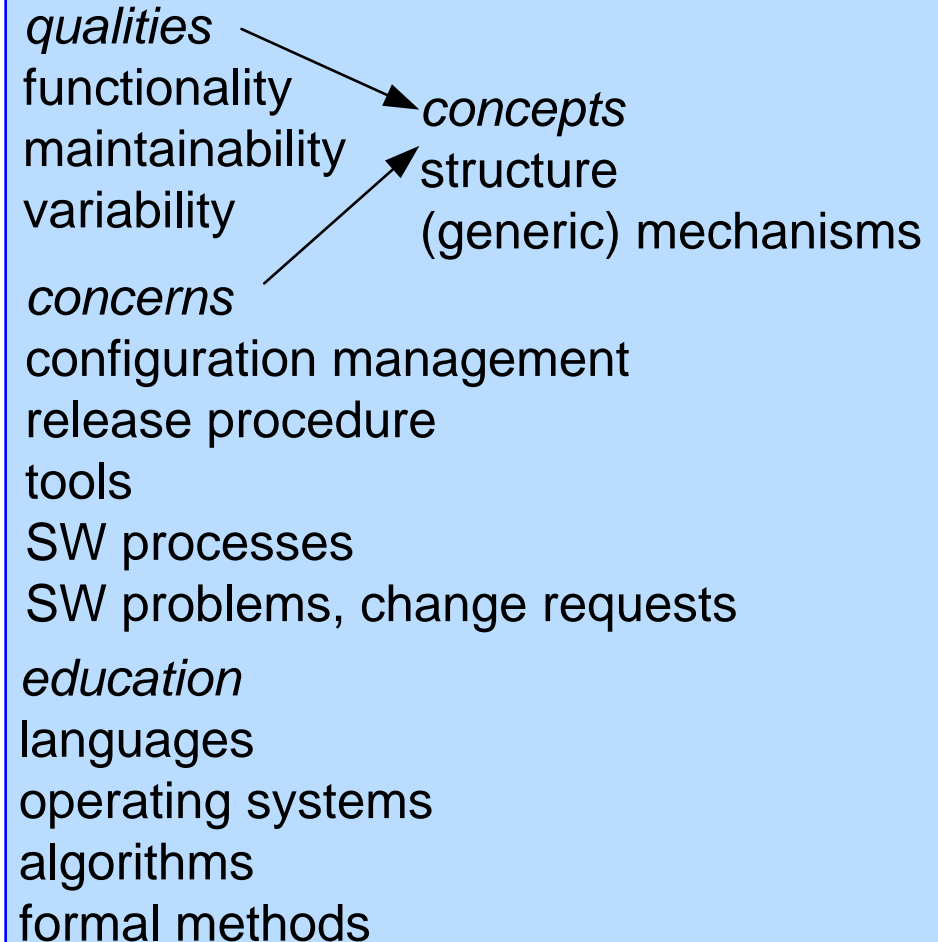


Different Focus of Software and System

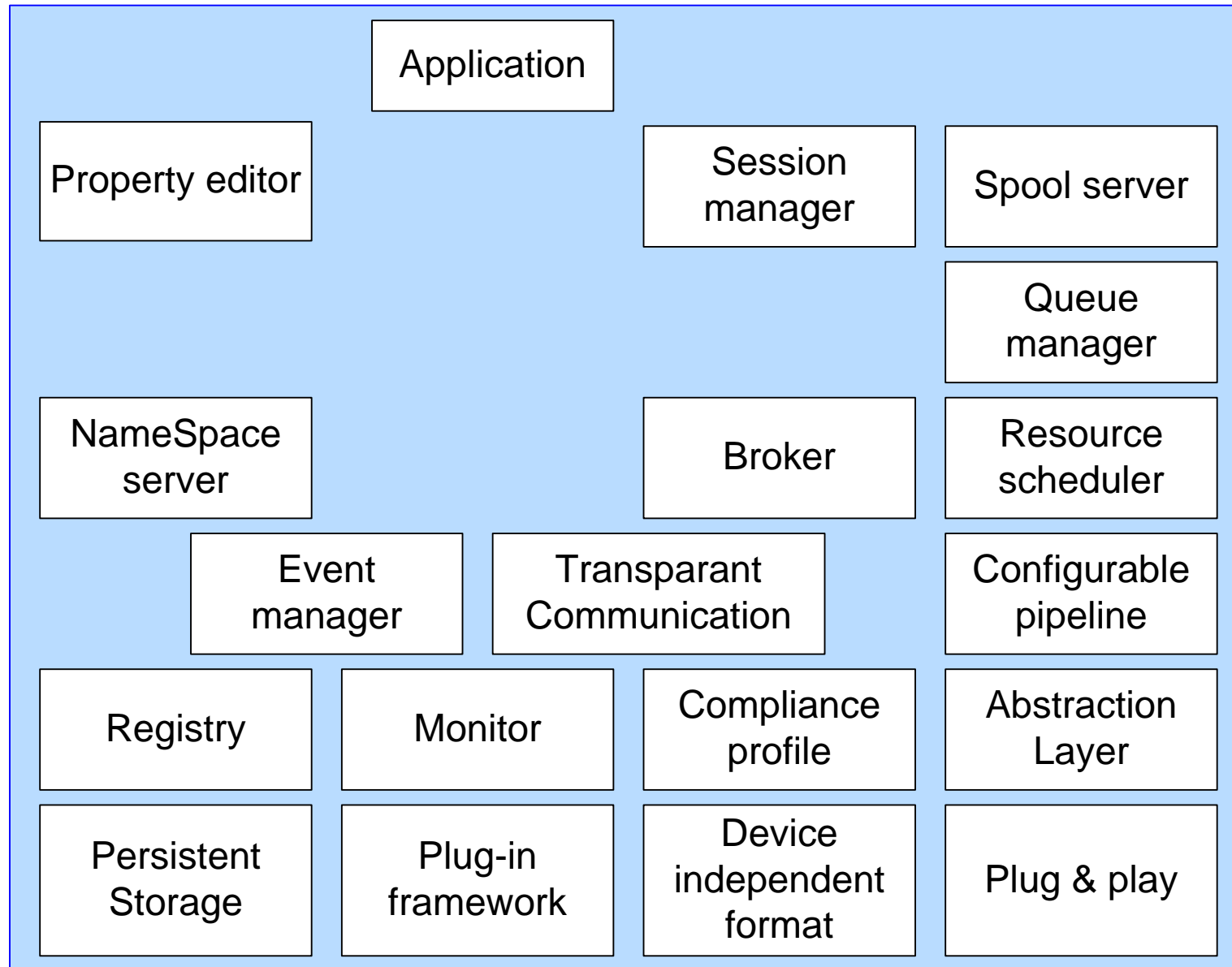
System engineering focus



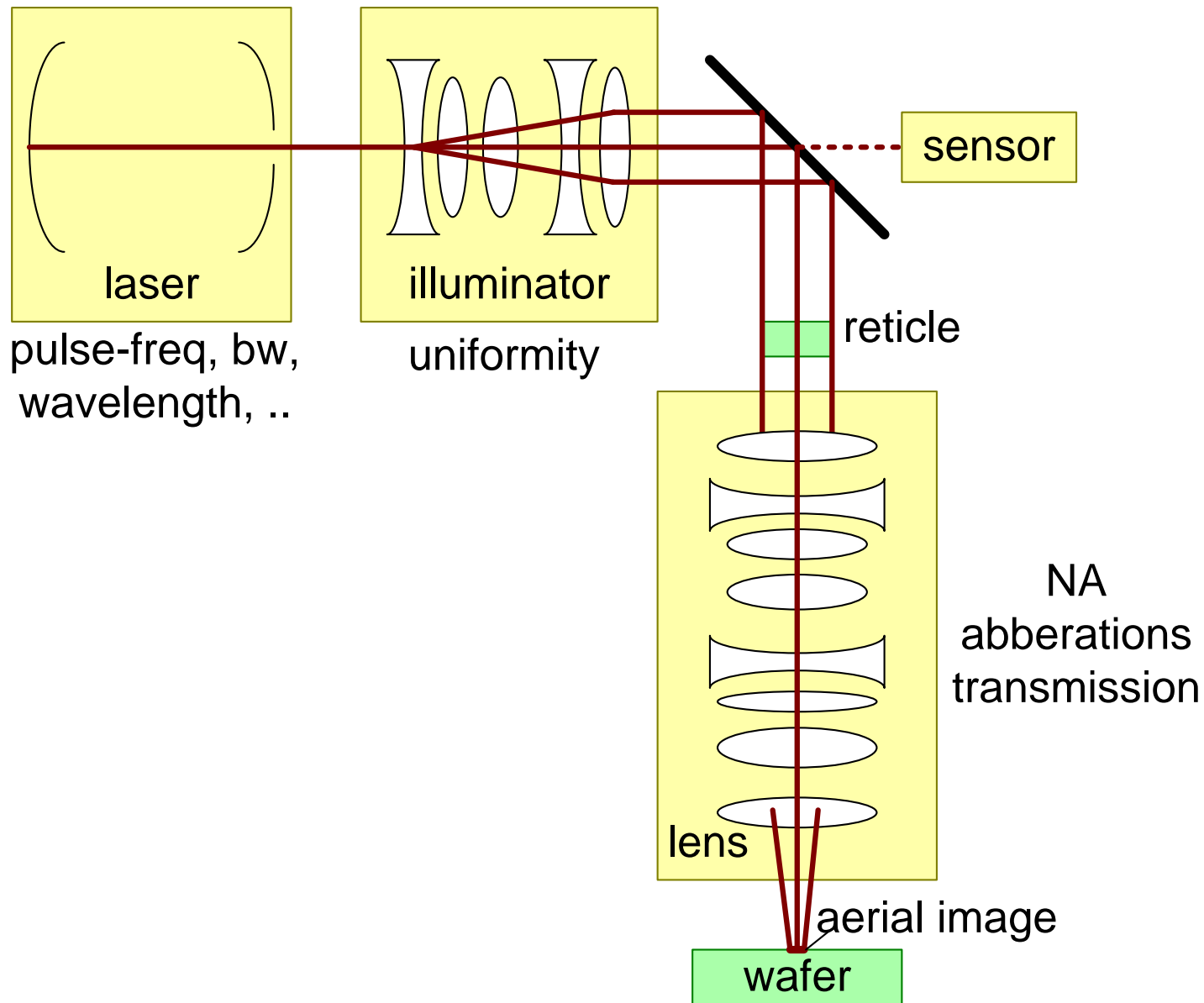
SW engineering focus



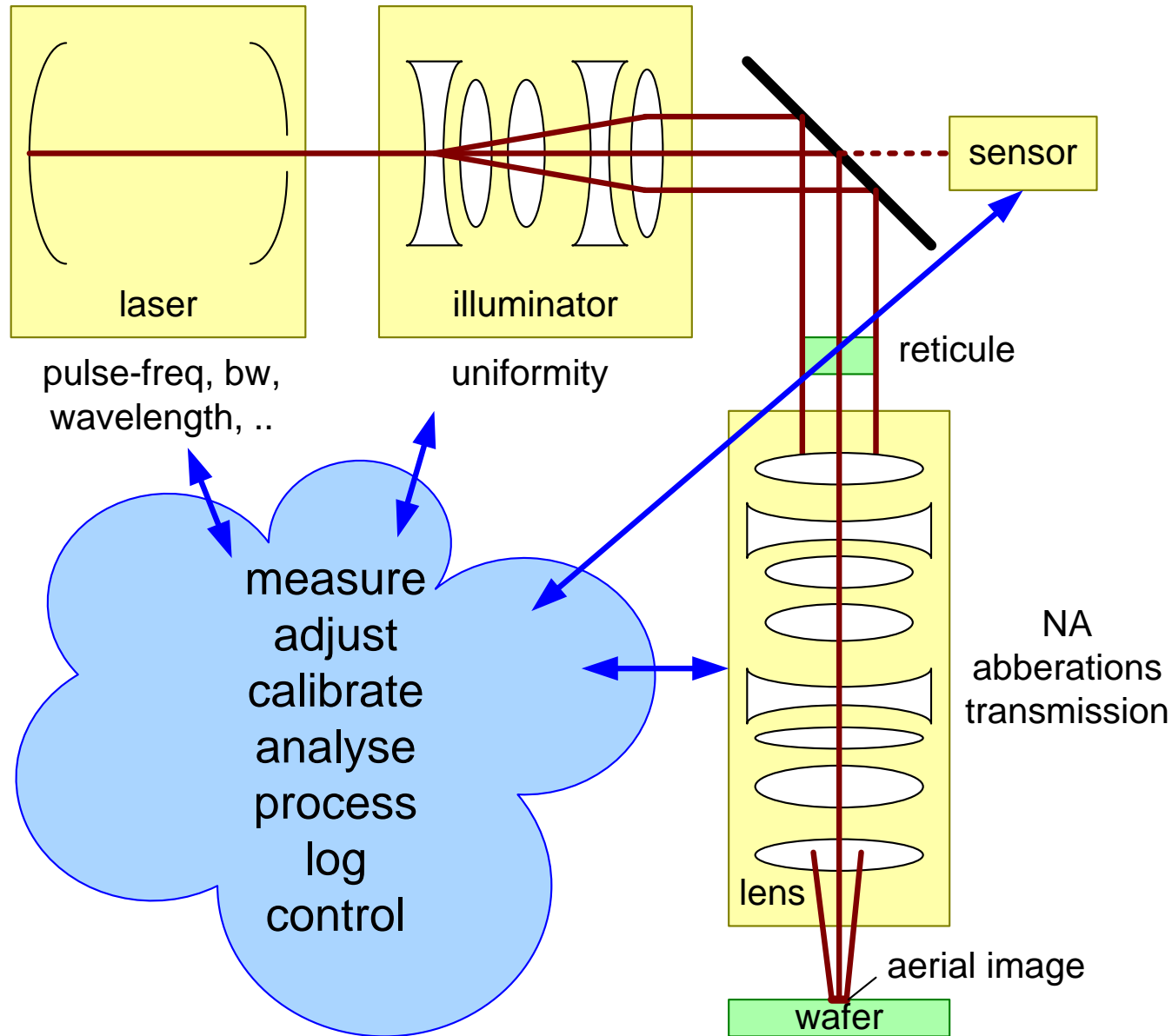
Caricature of a SW Architecture



Caricature of Physics Systems View



Relation SW and Physics



Symptoms of too isolated SW efforts

symptoms

counter measures

SW people are clustered together

colocation per function, subsystem or quality

SW is alpha tested before system integration

continuous system integration

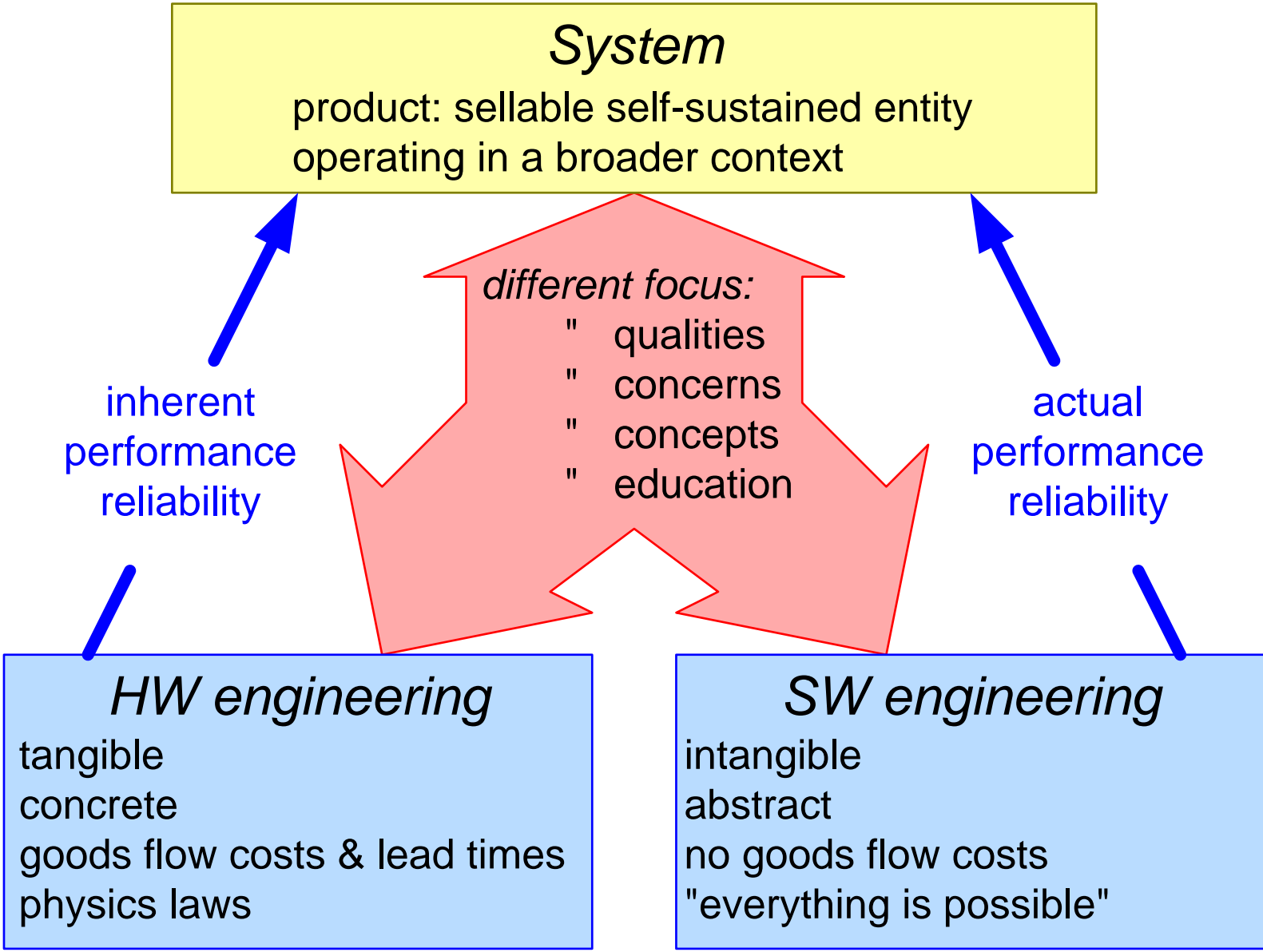
SW team uses own specification and design process

higher level processes are shared

SW specification is in SW jargon or formalism

interaction between SW,
HW and system engineers

Hardware Software System



Mastering Systems Integration; Product Families and Platforms

by *Gerrit Muller* [TNO-ESI, University of South-Eastern Norway]

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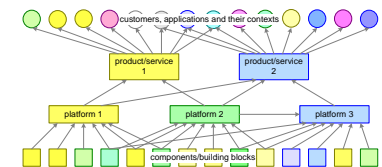
Abstract

Many systems, products, and services depend on sharing realizations of functions and subsystems. The organization may organize the sharing in platforms, such that the product developers focus primarily on their added value to the applications. Sharing, however, is a complication for integration. Changes in a component may propagate to various platforms to multiple products and services in widely different circumstances.

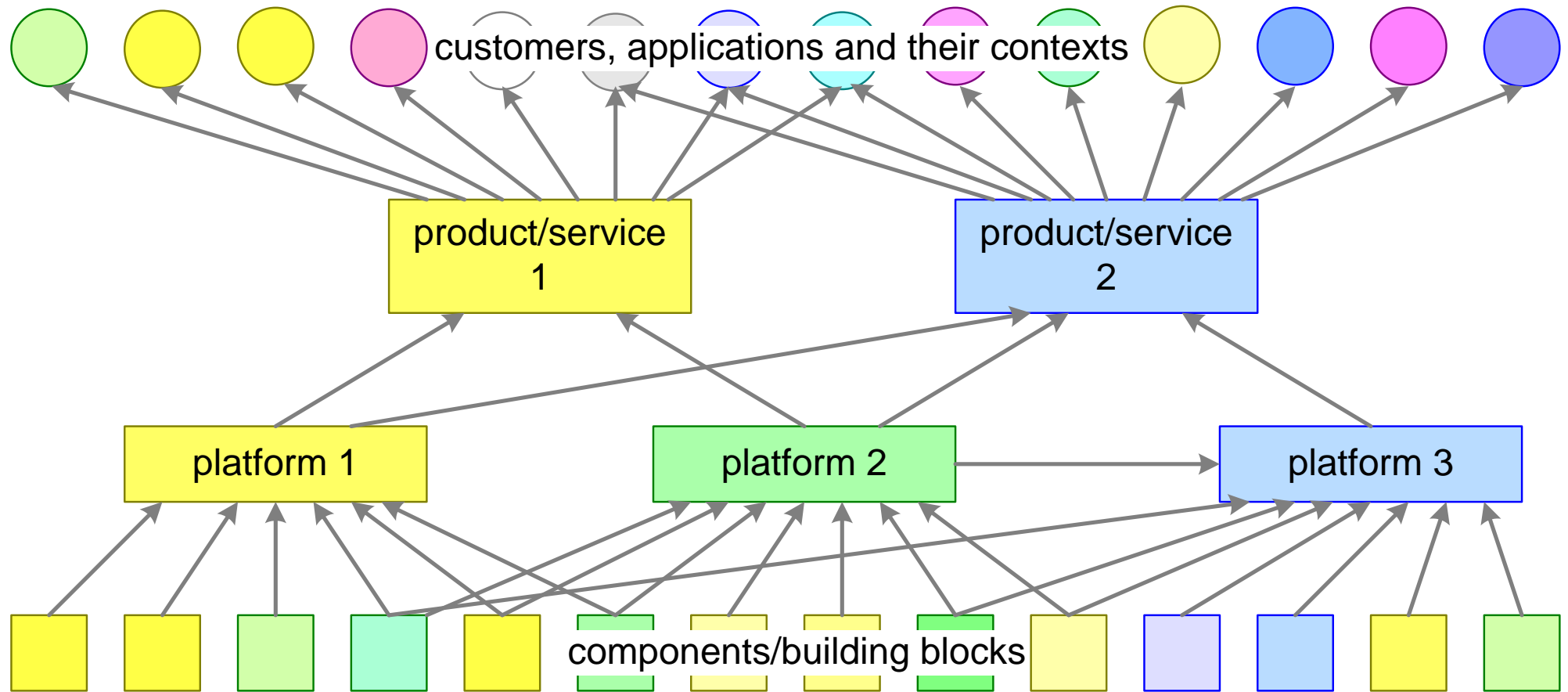
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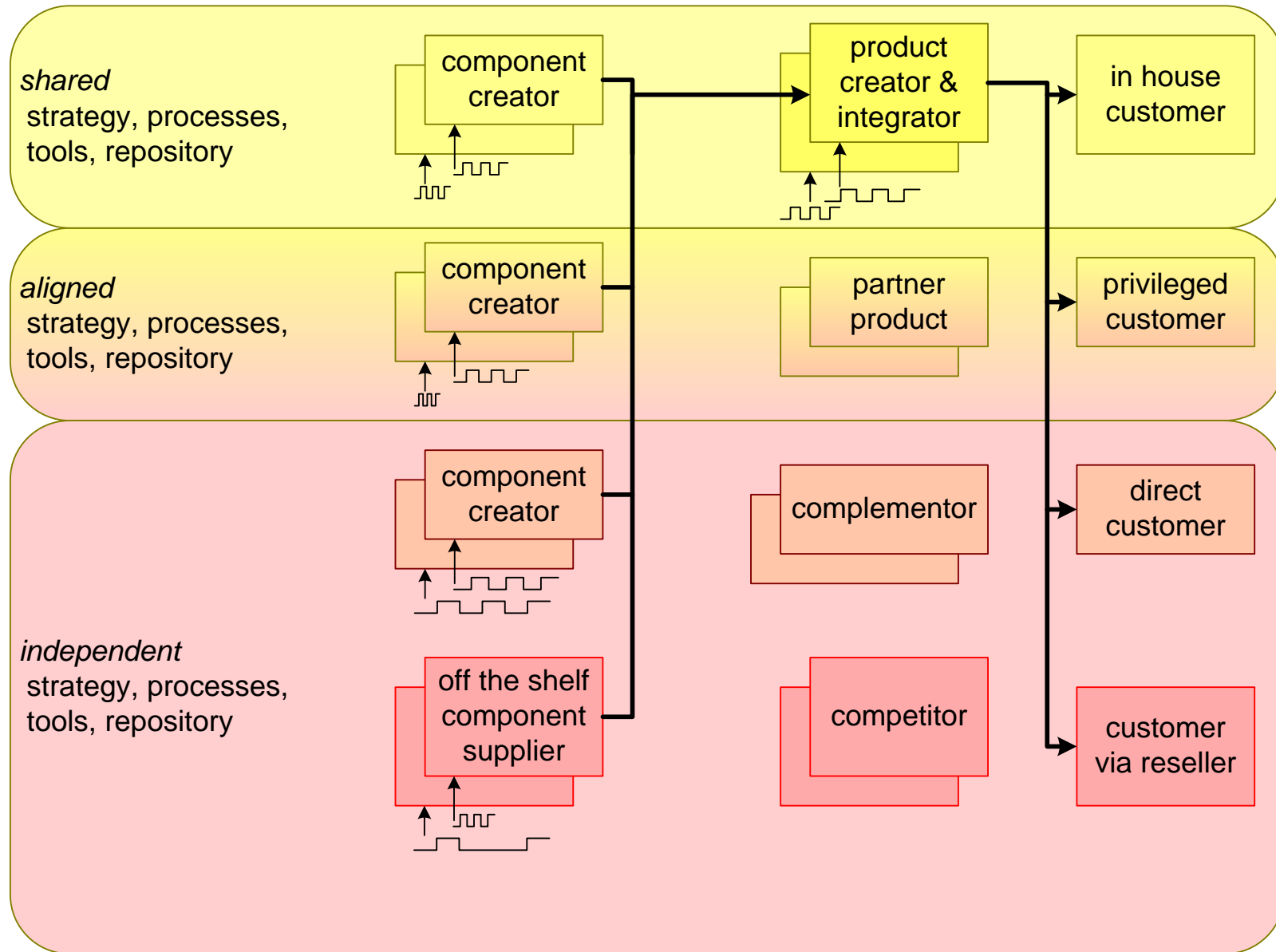
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version: 0.1



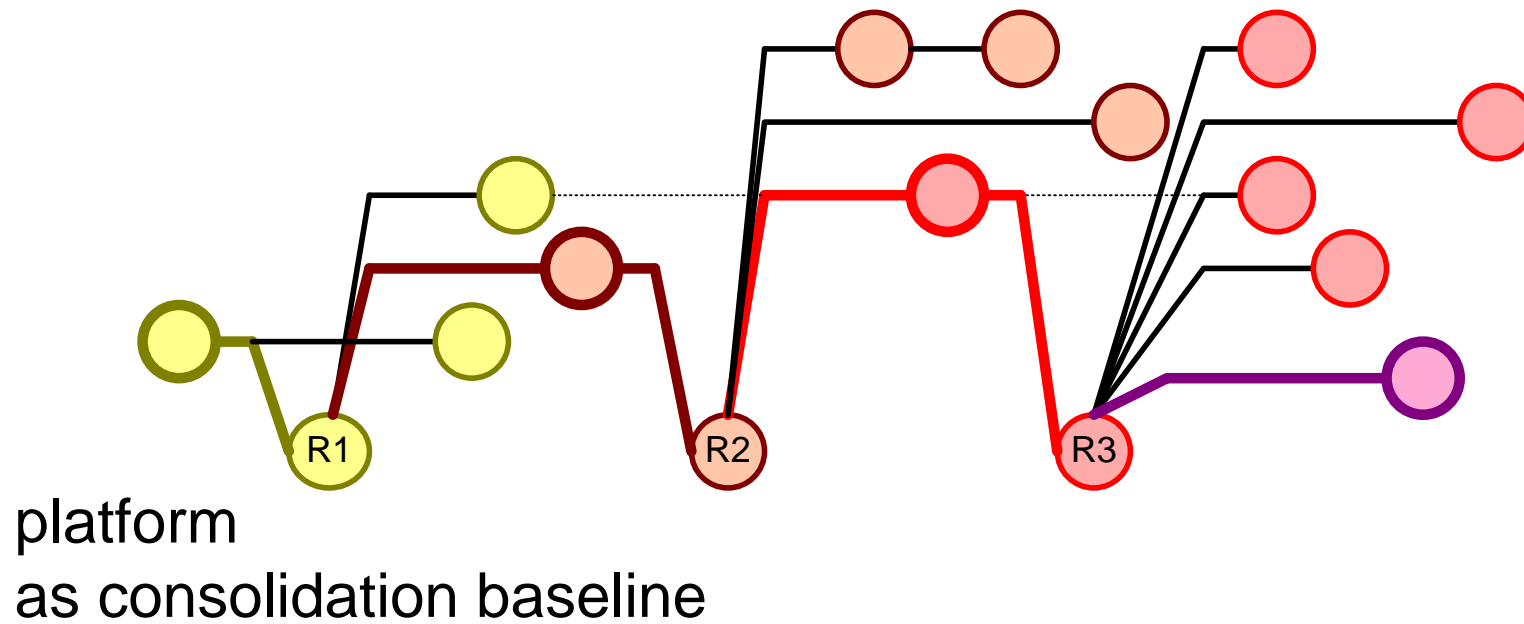
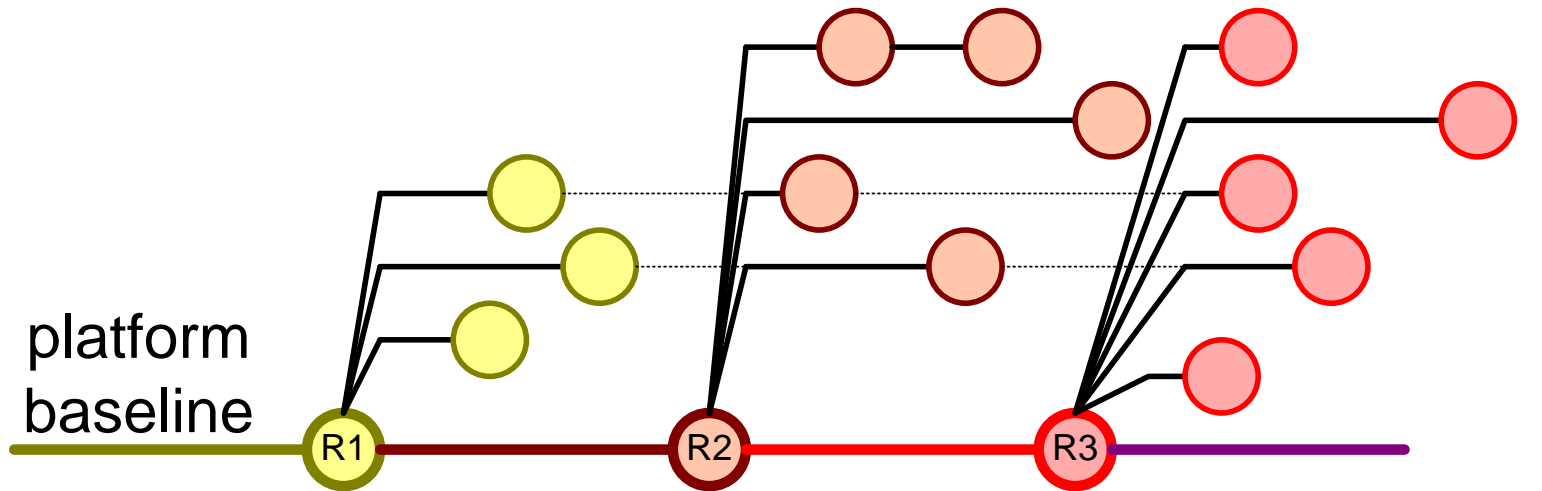
Dependency Network



Varying Clock Cycles across Creation Chain



Release Models for Platforms and Projects/Products



Mastering Systems Integration; Course Material

by *Gerrit Muller* TNO-ESI, University College of South-Eastern Norway

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Abstract

Listing the course material for the course Systems Integration

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The Systems Integration course is partially derived from the Systems Integration and Test course developed at *TNO-ESI* by *Teade Punter, Frans Beenker, and many others.*

Introduction

core

Mastering Systems Integration; Introduction

<http://gaudisite.nl/info/MSIintro.info.html>

optional

Course Overview

core

Mastering Systems Integration; Course Overview

<http://gaudisite.nl/info/MSloverview.info.html>

optional

Process and Positioning

core

Mastering Systems Integration; Process and Positioning

<http://gaudisite.nl/info/MSIprocessAndPositioning.info.html>

optional

SESA /SARCH Module 01, System Architecture Context

<http://gaudisite.nl/info/ModuleSystemArchitectureContext.info.html>

core

Course Systems Integration; Hardware, Software, System

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

optional

Tutorial Software as Integrating Technology in Complex Systems

<http://gaudisite.nl/info/TutorialSoftwareAsIntegratingTechnology.info.html>

core

Course Systems Integration; Terminology

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

optional

Understanding Objective Evidence: (What It Is and What It Definitely Is Not),
by Denise Dion

http://www.eduquest.net/Advisories/EduQuest%20Advisory_ObjectiveEvidence.pdf

List of Cognitive Biases, Wikipedia:

https://en.wikipedia.org/wiki/List_of_cognitive_biases

core

Mastering Systems Integration; Economic Perspective

<http://gaudisite.nl/info/MSIeconomicPerspective.info.html>

optional

Simplistic Financial Computations for System Architects.

<http://gaudisite.nl/info/SimplisticFinancialComputations.info.html>

Visualizing Dynamic Behavior

core

Visualizing Dynamic Behavior

<http://gaudisite.nl/info/VisualizingDynamicBehavior.info.html>

optional

Creating an A3 Architecture Overview; a Case Study in SubSea Systems by Gerrit Muller, Damien Wee, and Martin Moberg; INCOSE 2015 in Seattle, WA, USA

http://gaudisite.nl/INCOSE2015_MullerEtAl_SubseaOverviewA3.pdf

core

Course Systems Integration; Early Validation

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

optional

System Integration How-To

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

Save Money by Investing In Models; Failing Early is More affordable Than Failing Late

<http://gaudisite.nl/SaveMoneyInvestInModelsSlides.pdf>

Light Weight Architectures; The way of the future?

<http://gaudisite.nl/info/LightWeightArchitecting.info.html>

core

Course Systems Integration; Project Management

<http://gaudisite.nl/info/MSIprojectManagement.info.html>

optional

Combating Uncertainty in the Workflow of Systems Engineering Projects

INCOSE 2013, Barry Papke and Rick Dove

core

Course Systems Integration; Testing

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

optional

What is wrong with Reliability Engineering, by R.W.A. Barnard, Proceedings of INCOSE 2008 in Utrecht.

Highly accelerated life test

https://en.wikipedia.org/wiki/Highly_accelerated_life_test

Readiness Levels

core

Course Systems Integration; Readiness Levels

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

optional

From TRL to SRL: The Concept of Systems Readiness Levels

CSER 2006, Brian Sauser et al.

Technology Readiness Levels

https://en.wikipedia.org/wiki/Technology_readiness_level

core

Mastering Systems Integration; System of Systems

<http://gaudisite.nl/info/MSIsystemOfSystems.info.html>

optional

J. Dahmann and K. Baldwin. 2008. "Understanding the Current State of US Defense Systems of Systems and the Implications for Systems Engineering." IEEE Systems Conference 2008 in Montreal, 2008.

Boardman, J. and B. Sauser, System of Systems - the meaning of of, in IEEE/SMC International Conference on Systems of Systems Engineering. 2006, IEEE: Los Angeles.

Gorod, A., White, B.E., Ireland, V., Gandhi, J.S., and Sauser, B., (editors) "Case studies in System of Systems, Enterprise systems, and Complex Systems Engineering", CRC Press, 2014.

core

Course Systems Integration; Software and Integration

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

optional

Tutorial Software as Integrating Technology in Complex Systems

<http://gaudisite.nl/info/TutorialSoftwareAsIntegratingTechnology.info.html>