Architectural Reasoning Using Conceptual Modeling

by *Gerrit Muller*

University of South-Eastern Norway-NISE

Abstract

Multi-view architecting connects the system design to customer context and life cycle context. We teach an architecting method based on many views and fast iteration of the views. Visual models, functional models, and mathematical models in all views are the means to communicate about the system, to discuss specification and design choices, to reason about consequences, and to make decisions.

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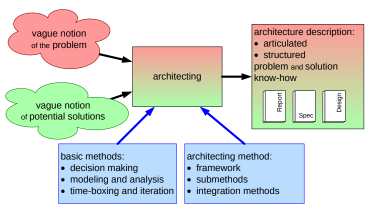

Module 30, Architectural Reasoning Introduction

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

This module introduces Architectural Reasoning using Conceptual Modeling.

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SEMA System Modeling and Analysis Course

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

The SEMA course System Modeling and Analysis is a 5 day course. Core of the course is Architectural Reasoning Using Conceptual Modeling. This course uses the CAFCR+ model with 6 views. Qualities connect all views. Threads-of-reasoning capture the architectural reasoning across views and qualities. Conceptual models visualize and capture the context, the system and its design. Quantification is a means to make problem and solution space tangible.

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day 1	introduction to modeling	exploring the case
day 2	sample customer space	functions and parts
day 3	customer space analysis	quantification and concepts
day 4	business and life cycle	integration and reasoning
day 5	modeling	wrap-up

Course Program

day 1	introduction to modeling	exploring the case
day 2	sample customer space	functions and parts
day 3	customer space analysis	quantification and concepts
day 4	business and life cycle	integration and reasoning
day 5	modeling	wrap-up

Preparation for the Course

During the SEMA course you work in teams of about 3 persons. Smaller teams (even single persons) are acceptable as well.

Every team preferably works on a real part of a system with some real development that goes on.

We start to model the status quo of the system and then we will model and analyze a change or addition that is being considered.

As preparation for the course I ask you the following:

- Look if the other participants are working on similar systems, such that you can work as team.
- Pick as team a system/component/function/project you will use during the course.
- For this system/component/function/project collect information about: who is the customer, what does the customer need, how is the system used, what technologies are used in the system, what are the main technological challenges et cetera. You do not have to be an expert when you come to the course, but you need to have some feeling for the system you will be working on during the course and presumably also in the 10 week project.
- If you are preparing your master project, then the master project case is probably a good option. This will boost your master project.

Assignments during the Course

1. elevator

Customer objectives | **A**pplication | **F**unctional | **C**onceptual | **R**ealization | **+** Life cycle

2. exploring the case

3. story telling

4. use case

5. dynamic behavior

6. block diagram

7. context and workflow

8 customer key driver graph

9. budget based design

10. concept selection

11. business plan

12. change analysis

13. line of reasoning

14. thread of reasoning

15. quantified chain of models

16. credibility and accuracy

Course Material Introduction

core

SEMA System Modeling and Analysis Course

http://www.gaudisite.nl/info/SEMAcourse.info.html

SEMA Basic Philosophy

http://www.gaudisite.nl/info/SEMAbasics.info.html

Physical Models of an Elevator

http://www.gaudisite.nl/info/ElevatorPhysicalModel.info.html

optional

Teaching conceptual modeling at multiple system levels using multiple views

http://www.gaudisite.nl/CIRP2014_Muller_TeachingConceptualModeling.pdf

Understanding the human factor by making understandable visualizations

http://www.gaudisite.nl/info/UnderstandingHumanFactorVisualizations.info.html

Dynamic Range of Abstraction Levels in Architecting

http://www.gaudisite.nl/info/DynamicRangeAbstractionLevels.info.html

Course Material CAFCR Scan

core
SEMA Method Overview
http://www.gaudisite.nl/info/SEMAmethodOverviewSlides.pdf
Short introduction to basic "CAFCR" model
http://www.gaudisite.nl/info/BasicCAFCR.info.html
InitialCAFCRscan
http://www.gaudisite.nl/info/InitialCAFCRscan.info.html
optional
Architectural Reasoning Explained
http://www.gaudisite.nl/ArchitecturalReasoningBook.pdf
Architectural Reasoning
http://www.gaudisite.nl/ArchitecturalReasoning.html
Iteration How To
http://www.gaudisite.nl/info/IterationHowTo.info.html
Modeling and Analysis: Iteration and Time-boxing
http://www.gaudisite.nl/info/MAiterationAndTimeboxing.info.html

Course Material Sample CA

core
Story How To
http://www.gaudisite.nl/info/StoryHowTo.info.html
Use Case How To
http://www.gaudisite.nl/info/UseCases.info.html
optional
Story Telling in Medical Imaging
http://www.gaudisite.nl/info/MIstories.info.html

Course Material Design Fundamentals

core
System Partitioning Fundamentals
http://www.gaudisite.nl/info/SystemPartitioningFundamentals.info.html
optional
Basic Working Methods of a System Architect
http://www.gaudisite.nl/info/BasicWorkingMethodArchitect.info.html
SubSea Modeling Example
http://www.gaudisite.nl/SubSeaModelingExampleSlides.pdf

Course Material Customer Space Analysis

core
Methods to Explore the Customer Perspective
http://www.gaudisite.nl/info/MethodsToExploreTheCustomerPerspective.info.html
Key Drivers How To
http://www.gaudisite.nl/info/KeyDriversHowTo.info.html
optional
Medical Imaging Workstation: CAF Views
http://www.gaudisite.nl/info/MIviewsCAF.info.html

Course Material Conceptual Design

core

Modeling and Analysis: Budgeting

http://www.gaudisite.nl/info/MAbudgeting.info.html

Concept Selection, Set Based Design and Late Decision Making

http://www.gaudisite.nl/info/ConceptSelectionSetBased.info.html

optional

The Tool Box of the System Architect

http://www.gaudisite.nl/info/ToolBoxSystemArchitect.info.html

Course Material Business and Life Cycle

core

Simplistic Financial Computations for System Architects.

http://www.gaudisite.nl/info/SimplisticFinancialComputations.info.html

Modeling and Analysis: Life Cycle Models

http://www.gaudisite.nl/info/MAlifeCycle.info.html

optional

How to present architecture issues to higher management

http://www.gaudisite.nl/info/ArchitectManagementInteraction.info.html

Course Material Integration and Reasoning

core

Qualities as Integrating Needles

http://www.gaudisite.nl/info/QualityNeedles.info.html

Threads of Reasoning

http://www.gaudisite.nl/info/ThreadsOfReasoning.info.html

Threads of reasoning illustrated by medical imaging case

http://www.gaudisite.nl/PresentationMITORSlides.pdf

Course Material Modeling

core

Modeling and Analysis: Reasoning Approach

http://www.gaudisite.nl/info/MAreasoningApproach.info.html

Modeling and Analysis: Analysis

http://www.gaudisite.nl/info/MAanalysis.info.html

optional

Modeling and Analysis: Measuring

http://www.gaudisite.nl/info/MAmeasuring.info.html

ASP Python Exercise

http://www.gaudisite.nl/info/ASPpythonExercise.info.html

Course Material Wrap-up

core
Consolidating Architecture Overviews
http://www.gaudisite.nl/info/ConsolidatingArchitectureOverviewsSlides.pdf
SEMA Homework Assignment
http://www.gaudisite.nl/info/SEMAhomeworkAssigmentSlides.pdf

optional
Guidelines for Visualization
http://www.gaudisite.nl/info/VisualizationGuidelines.info.html
Granularity of Documentation
http://www.gaudisite.nl/info/DocumentationGranularity.info.html
Light Weight Review Process
http://www.gaudisite.nl/info/LightWeightReview.info.html
Cookbook A3 Architecture Overview *by Daniel Borches*
http://www.gaudisite.nl/BorchesCookbookA3architectureOverview.pdf
How to Create an Architecture Overview
http://www.gaudisite.nl/info/OverviewHowTo.info.html

SEMA Basic Philosophy

by *Gerrit Muller* University of South-Eastern Norway-NISE
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`www.gaudisite.nl`

Abstract

This presentation explains the basic philosophy behind the SEMA course. The SEMA course in the first place is a course that provides an approach to architectural reasoning. Core to architectural reasoning is the ability to make conceptual models and to use them in conjunction. The course discusses how to make conceptual mdoels, how to get input, and how to use them for analysis. Modeling is put in broader perspective, such as model evolution, simuation, and validation.

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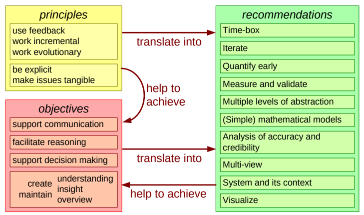


You will mostly be working!

One **Case** during the course and the home work assigment

Work in **teams** if possible

Select a case close to **your day-to-day practice**

Learning by Doing

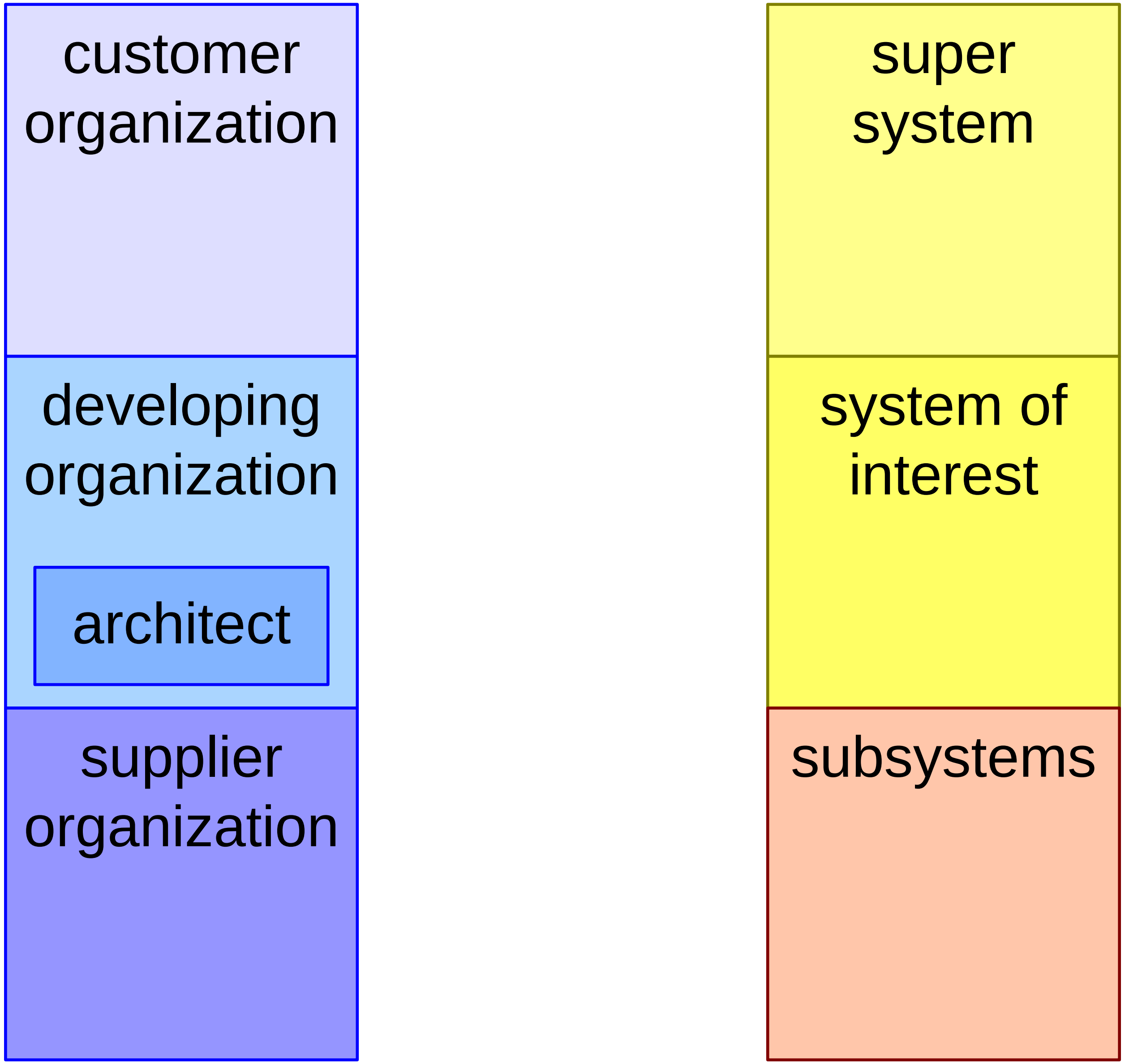
Some theory, apply on case

Case = System of interest + developing organization + some innovative change

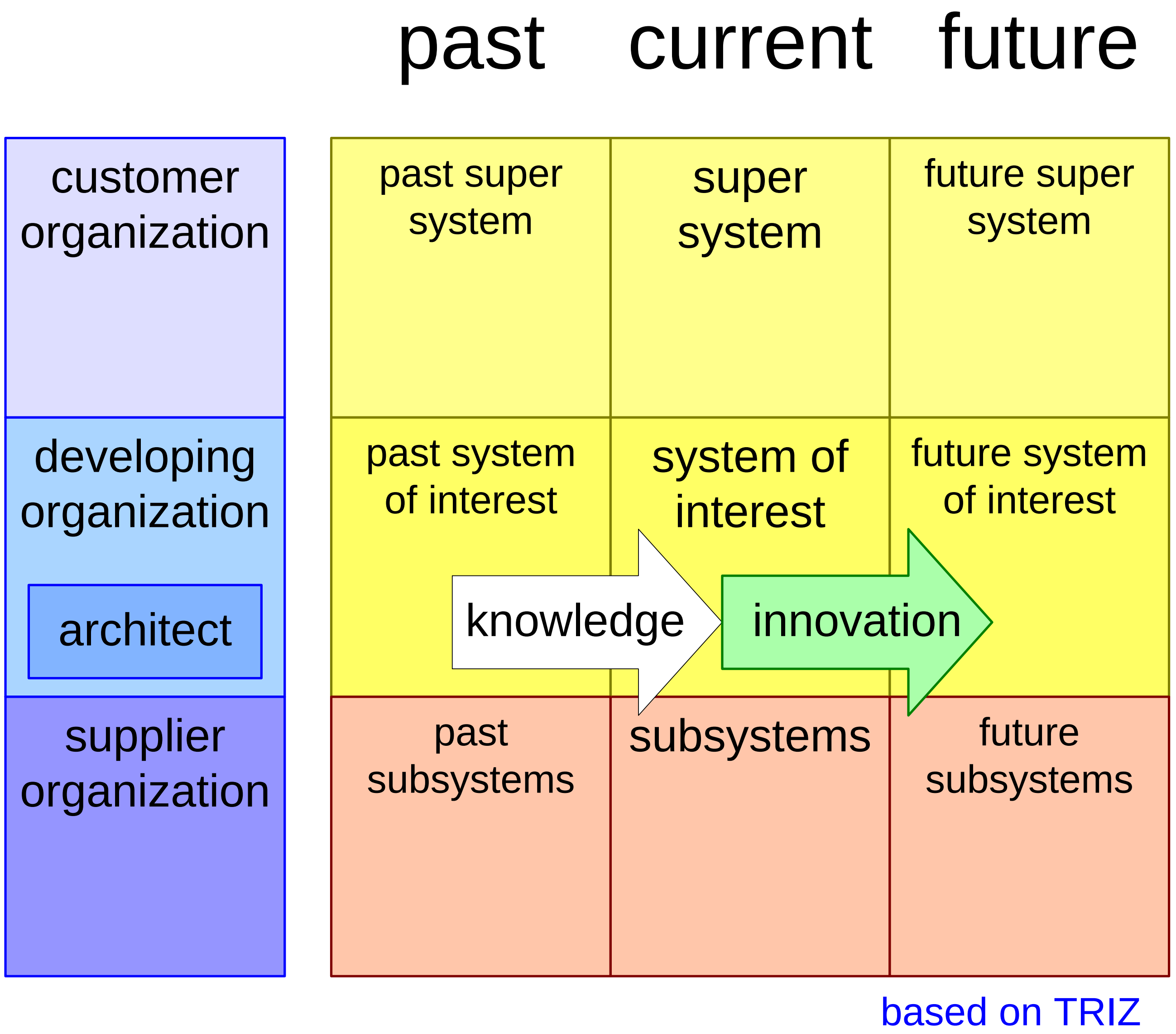
Choice of case is critical!

Our Primary Interest

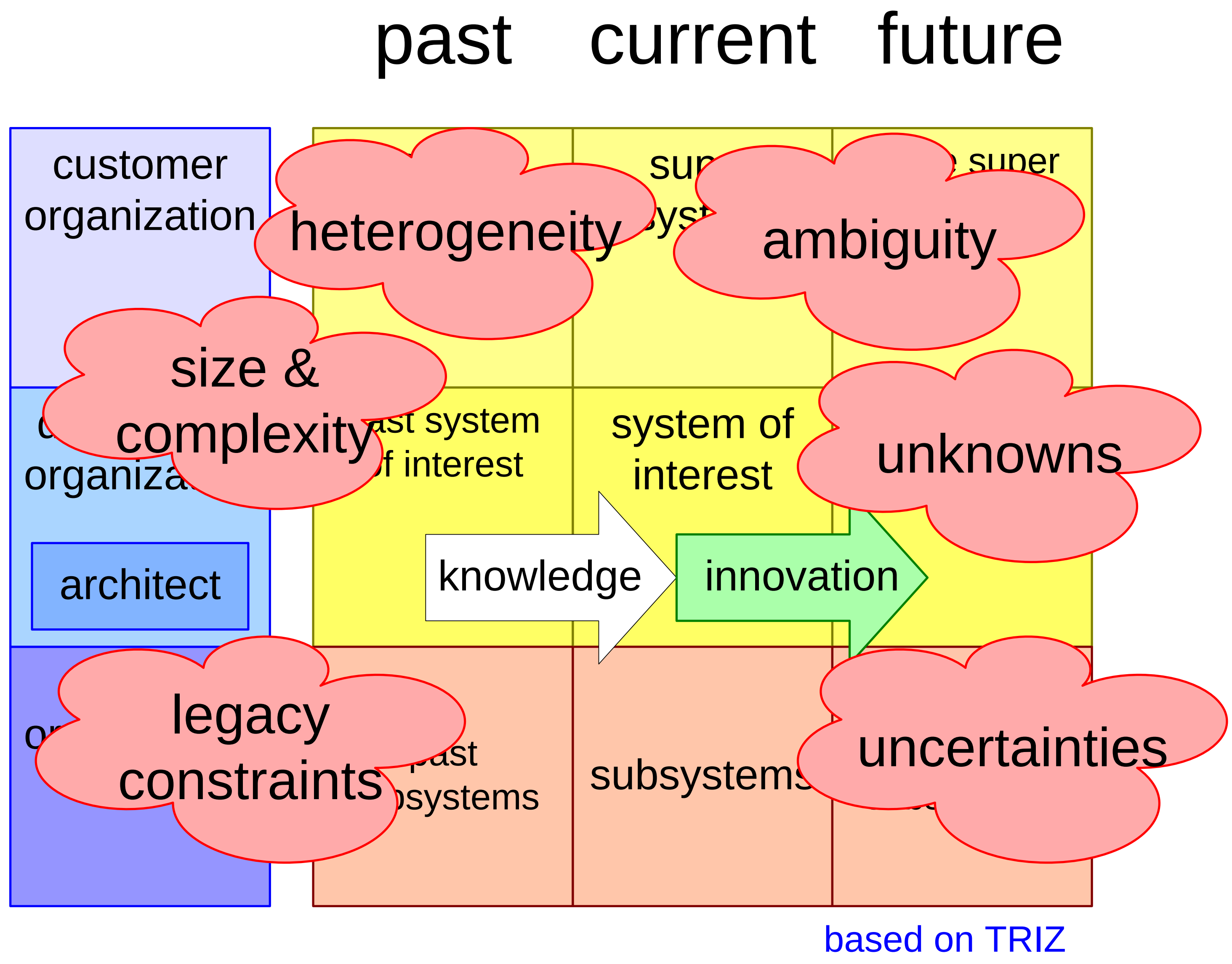
Context, Zoom-out and Zoom-in



Adding the Time Dimension

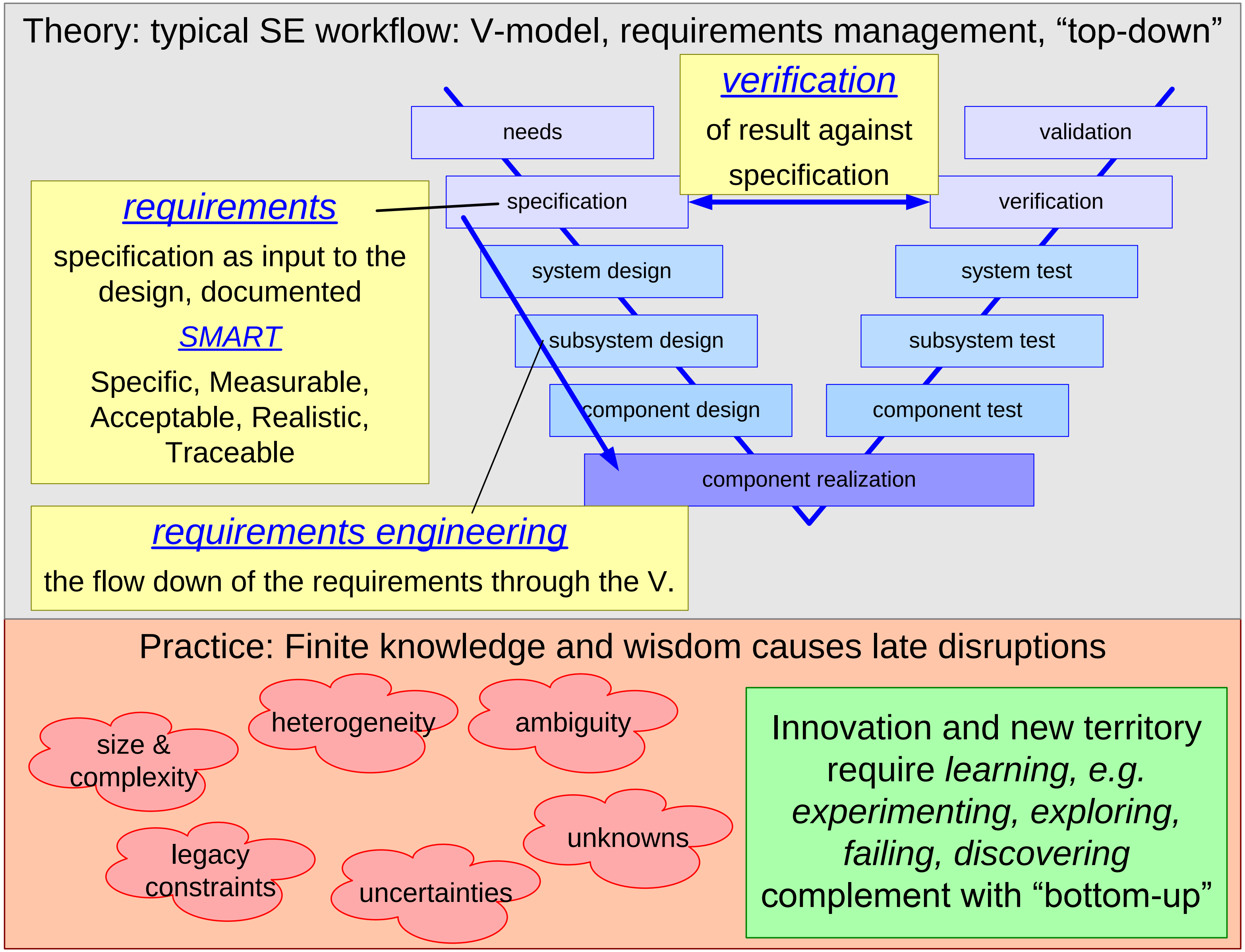


Challenges

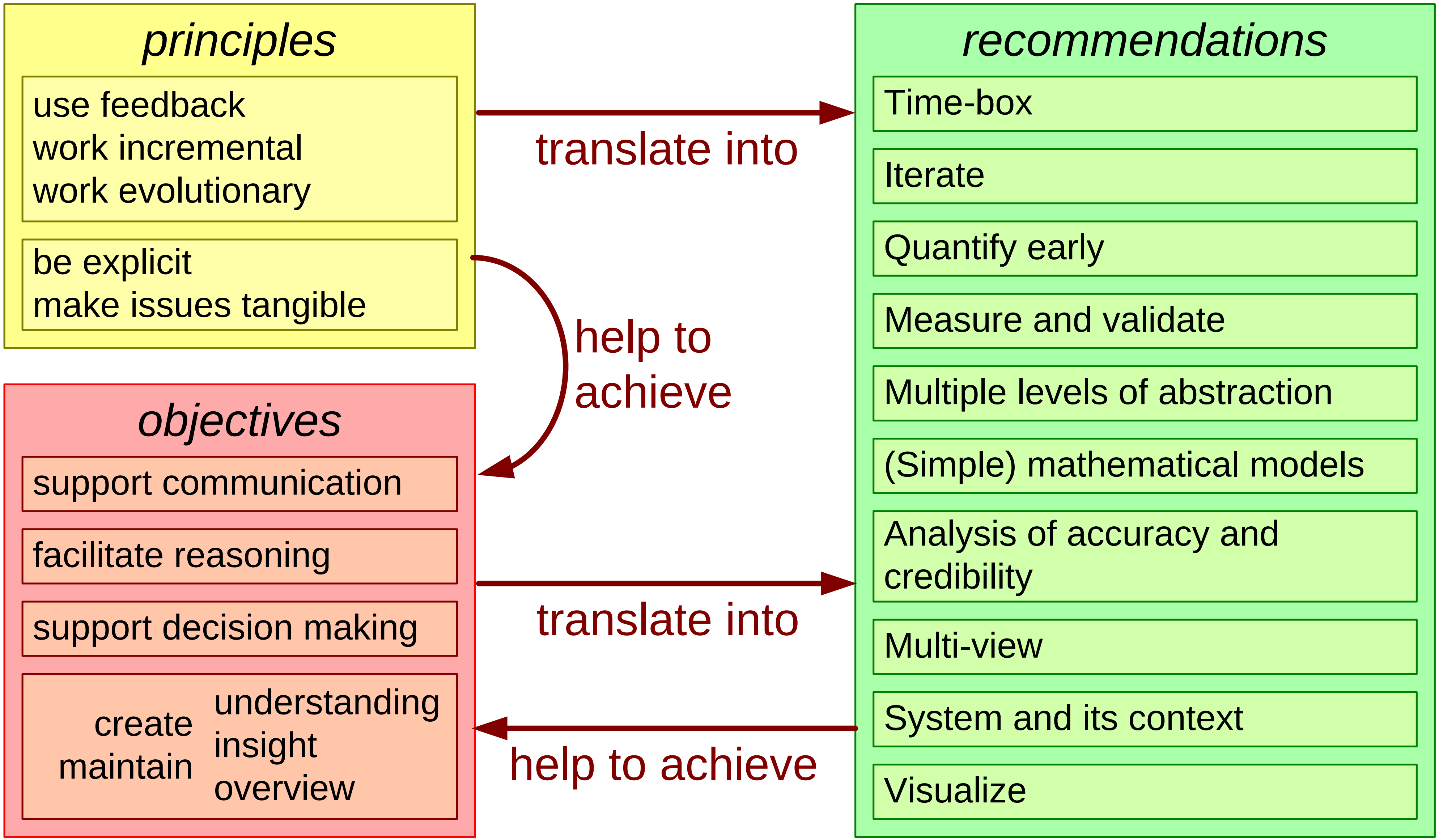


past
current
future
customer organization
heterogeneity
sup
syst
ambiguity
super
size &
complexity
organiza
ast system
f interest
system of interest
unknowns
architect
knowledge
innovation
legacy constraints
or
ast
bsystems
subsystems
uncertainties
based on TRIZ

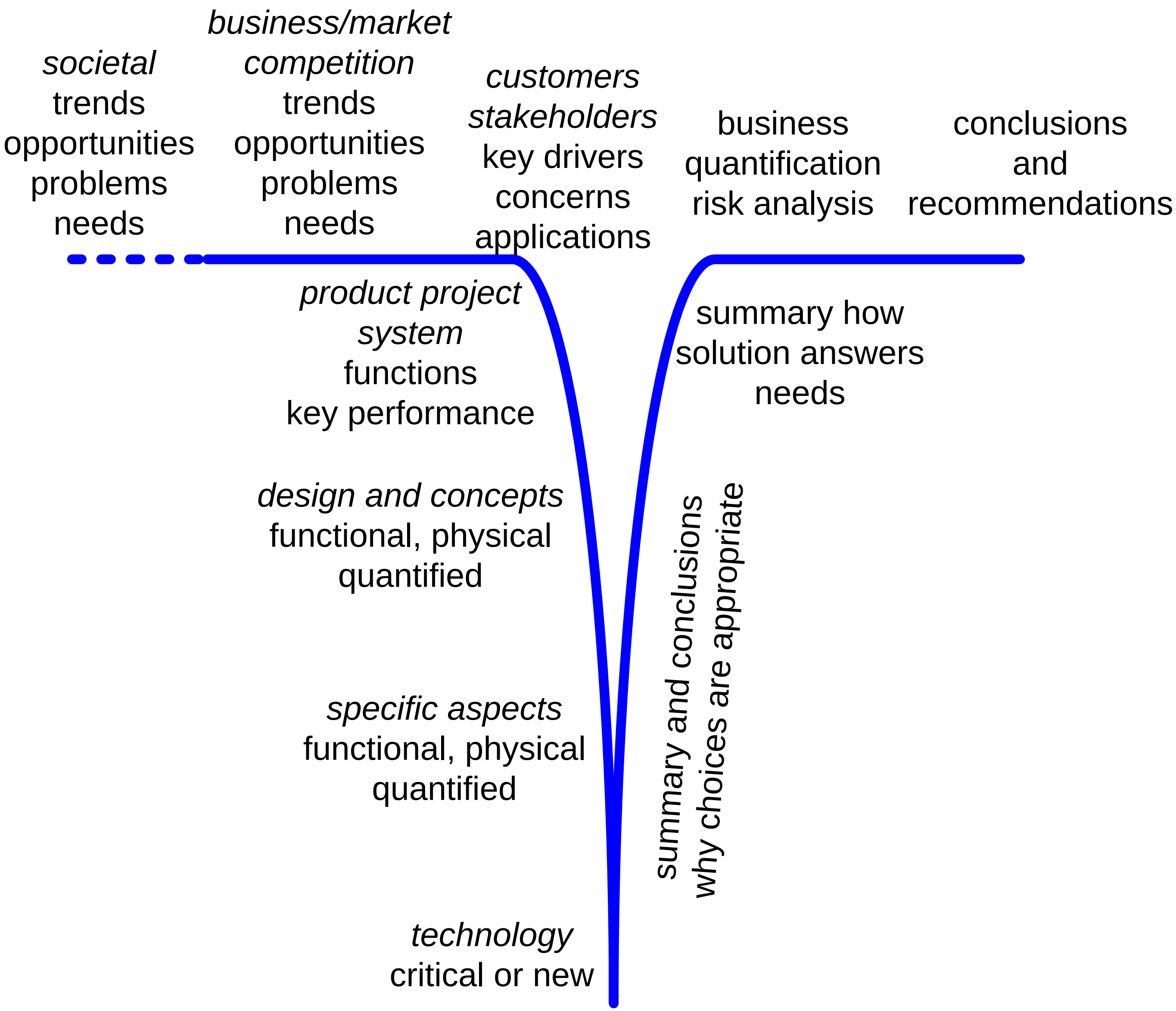
From Theory to Practice



Recommendations as Common Thread



Final Delivery: Presentation to Top Management



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.

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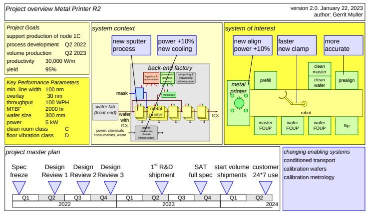


Project Overview Canvas

Project Title

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

Project Goals

- specific and quantified

Key Performance Parameters

- specific and quantified

system context

- visualization (drawing, block diagram, 3D model, or photo) of the system context
- indication of changes in the context

system of interest

- visualization (drawing, block diagram, 3D model, or photo) of the system
- indication of changes in the system of interest

project master plan with timeline

- timeline with 5 to 10 milestones, especially deliverables
- specific and quantified

optional information, e.g.

- 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

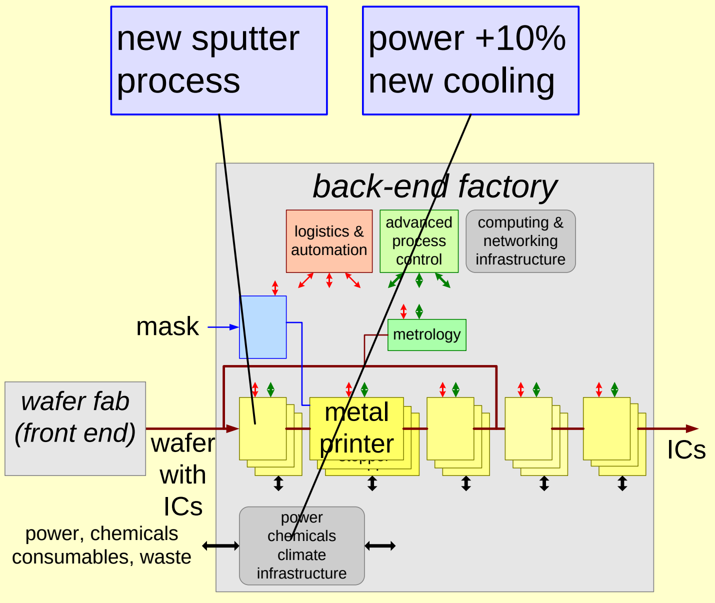
Project Goals

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

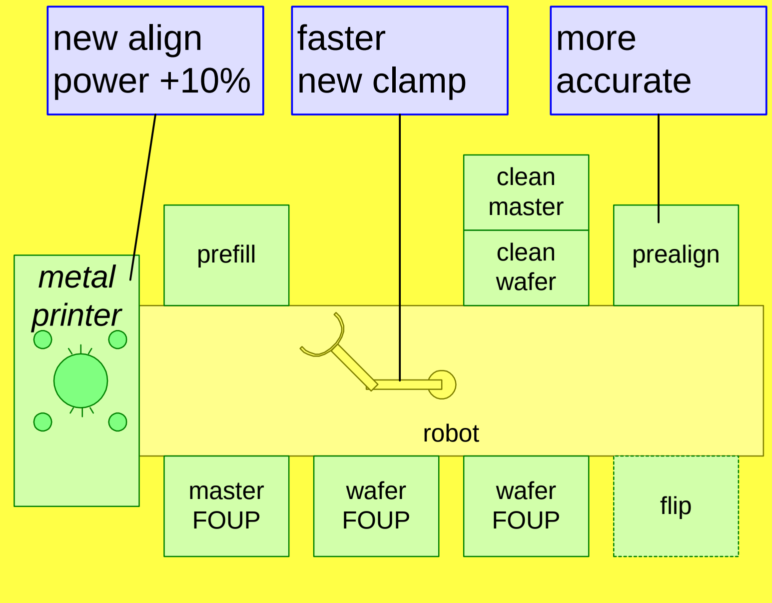
Key Performance Parameters

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

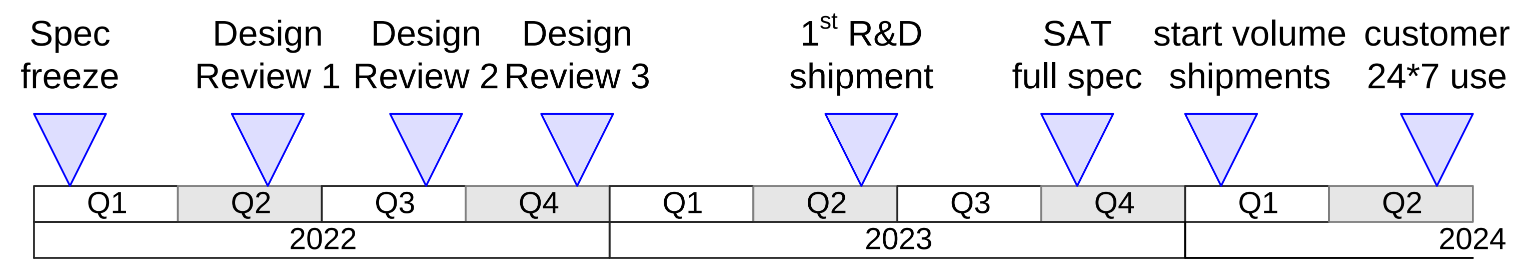
system context



system of interest



project master plan



changing enabling systems

conditioned transport
calibration wafers
calibration metrology

Project Overview Canvas

Project Title

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

Work Breakdown Structure

- visualization
- *builds upon the Product Breakdown Structure*

Project Master Plan

- PERT plan with major milestones

project organization

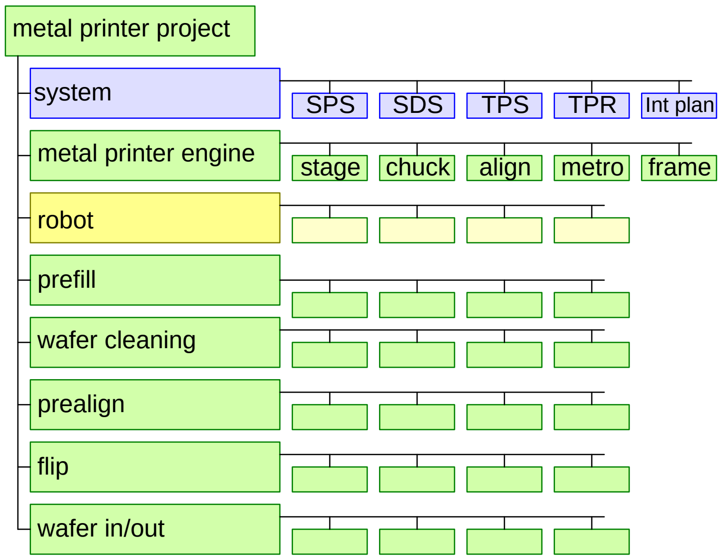
- allocation of roles
- specific additions or deviations

Example Project Overview

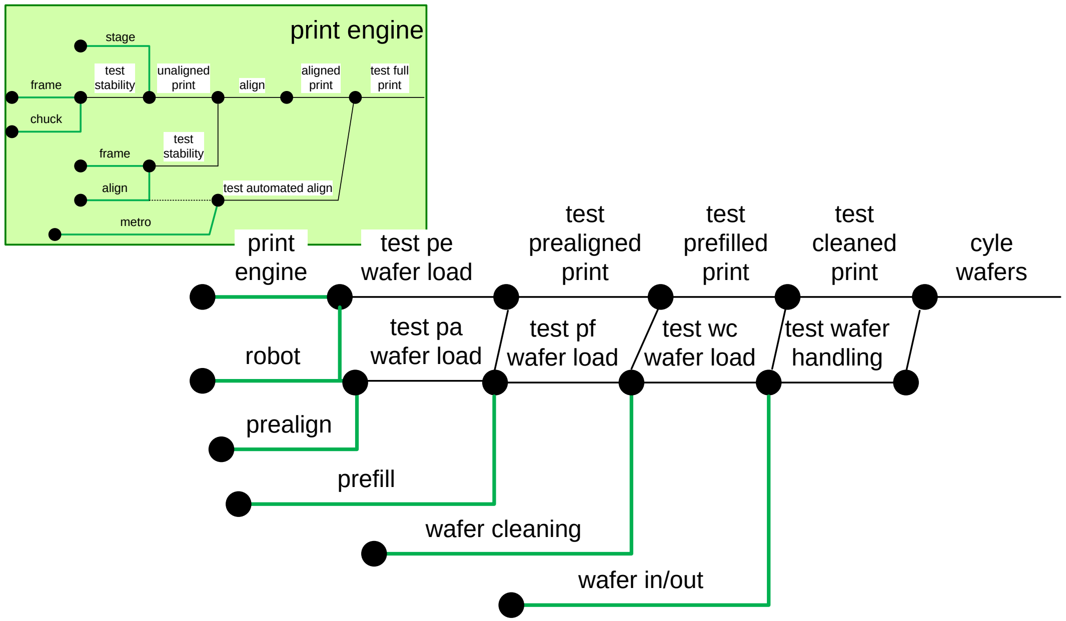
Metal Printer

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

Case Selection

Determine the system of interest

Define your organization

Determine an innovative change to be architected

Sketch the System-of-Interest

Sketch the **System-of-Interest** in its **context**

- Show some of the internals of the system-of-interest
- Indicate the boundary of the system-of-interest

Physical Models of an Elevator

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

An elevator is used as a simple system to model a few physical aspects. We will show simple kinematic models and we will consider energy consumption. These low level models are used to understand (physical) design considerations. Elsewhere we discuss higher level models, such as use cases and throughput, which complement these low level models.

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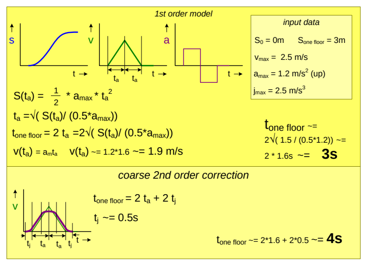


Learning Goals

To understand the need for

- various views, e.g. physical, functional, performance
- mathematical models
- quantified understanding
- assumptions (when input data is unavailable yet) and later validation
- various visualizations, e.g. graphs
- understand and hence model at multiple levels of abstraction
- starting simple and expanding in detail, views, and solutions gradually, based on increased insight

To see the value and the limitations of these conceptual models

To appreciate the complementarity of conceptual models to other forms of modeling, e.g. problem specific models (e.g. structural or thermal analysis), SysML models, or simulations

warning

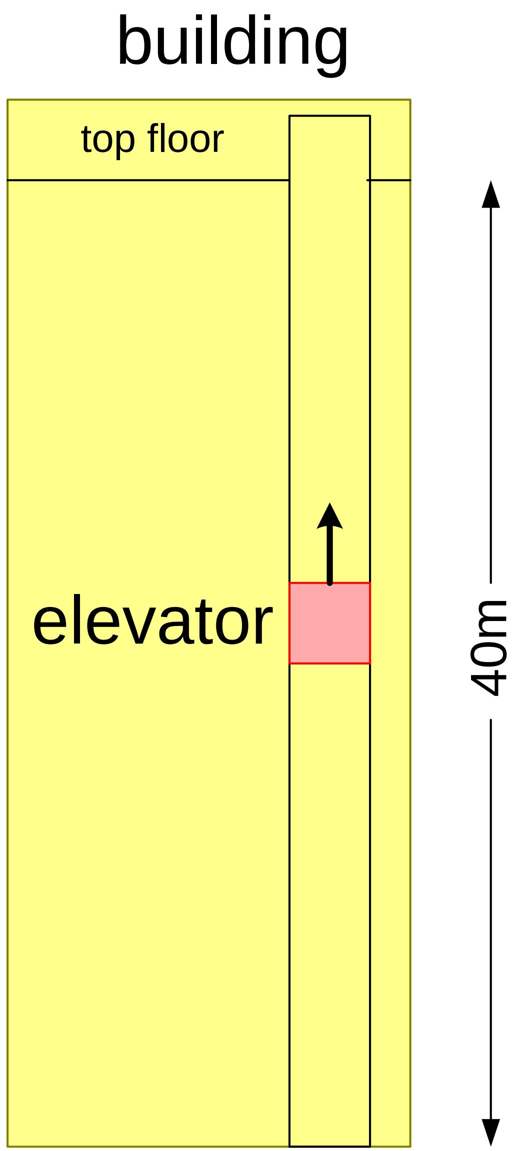
This presentation starts with a trivial problem.

Have patience!

Extensions to the trivial problem are used to illustrate many different modeling aspects.

Feedback on correctness and validity is appreciated

The Elevator in the Building



inhabitants want to reach
their destination fast and comfortable

building owner and *service operator*
have economic constraints:
space, cost, energy, ...

Elementary Kinematic Formulas

S_t = position at time t

v_t = velocity at time t

a_t = acceleration at time t

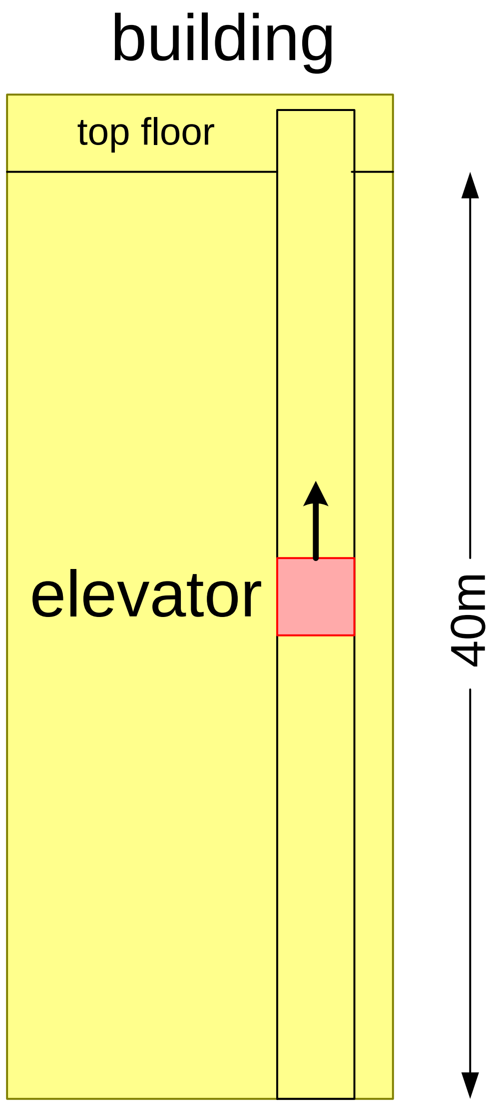
j_t = jerk at time t

$$v = \frac{dS}{dt} \qquad a = \frac{dv}{dt} \qquad j = \frac{da}{dt}$$

Position in case of uniform acceleration:

$$S_t = S_0 + v_0 t + \frac{1}{2} a_0 t^2$$

Initial Expectations



What values do you expect or prefer for these quantities? Why?

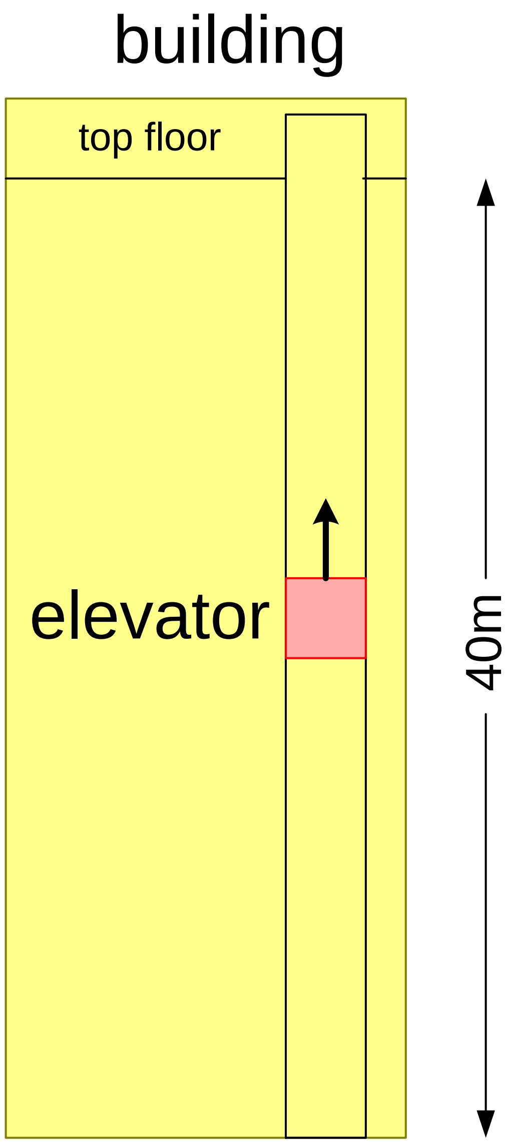
$t_{top\ floor}$ = time to reach top floor

v_{max} = maximum velocity

a_{max} = maximum acceleration

j_{max} = maximum jerk

Initial Estimates via Googling



Google "elevator" and "jerk":

$t_{top\ floor}$ ~= 16 s

v_{max} ~= 2.5 m/s

12% of gravity;
weight goes up

a_{max} ~= 1.2 m/s^2 (up)

relates to motor design
and energy consumption

j_{max} ~= 2.5 m/s^3

relates to control design

humans feel changes of forces
high jerk values are uncomfortable

numbers from: http://www.sensor123.com/vm_eva625.htm
CEP Instruments Pte Ltd Singapore

Exercise Time to Reach Top Floor Kinematic

input data

S_0 = 0m S_t = 40m

v_{max} = 2.5 m/s

a_{max} = 1.2 m/s^2 (up)

j_{max} = 2.5 m/s^3

elementary formulas

$$v = \frac{dS}{dt} \qquad a = \frac{dv}{dt} \qquad j = \frac{da}{dt}$$

Position in case of uniform acceleration:

$$S_t = S_0 + v_0 t + \frac{1}{2} a_0 t^2$$

exercises

$t_{top\ floor}$ is time needed to reach top floor without stopping

Make a model for $t_{top\ floor}$ and calculate its value

Make 0^e order model, based on constant velocity

Make 1^e order model, based on constant acceleration

What do you conclude from these models?

Models for Time to Reach Top Floor

input data

$S_0 = 0m$ $S_{top\ floor} = 40m$

$v_{max} = 2.5\ m/s$

$a_{max} = 1.2\ m/s^2$ (up)

$j_{max} = 2.5\ m/s^3$

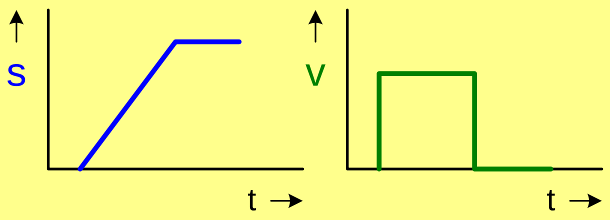
elementary formulas

$$v = \frac{dS}{dt} \qquad a = \frac{dv}{dt} \qquad j = \frac{da}{dt}$$

Position in case of uniform acceleration:

$$S_t = S_0 + v_0 t + \frac{1}{2} a_0 t^2$$

0th order model

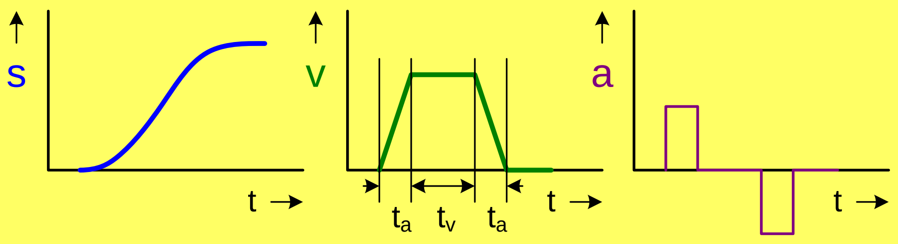


$S_{top\ floor} = v_{max} * t_{top\ floor}$

$t_{top\ floor} = S_{top\ floor} / v_{max}$

$t_{top\ floor} = 40/2.5 =$ **16s**

1st order model



$t_{top\ floor} = t_a + t_v + t_a$

$t_a = v_{max} / a_{max}$

$S(t_a) = \frac{1}{2} * a_{max} * t_a^2$

$S_{linear} = S_{top\ floor} - 2 * S(t_a)$

$t_v = S_{linear} / v_{max}$

$t_a \sim= 2.5/1.2 \sim= 2s$

$S(t_a) \sim= 0.5 * 1.2 * 2^2$

$S(t_a) \sim= 2.4m$

$t_v \sim= (40-2*2.4)/2.5$

$t_v \sim= 14s$

$t_{top\ floor} \sim= 2 + 14 + 2$

$t_{top\ floor} \sim=$ **18s**

Conclusions Move to Top Floor

Conclusions

v_{max} dominates traveling time

The model for the large height traveling time can be simplified into:

$$t_{travel} = S_{travel}/v_{max} + (t_a + t_j)$$

Exercise Time to Travel One Floor

input data

$S_0 = 0m$ $S_{top\ floor} = 40m$

$v_{max} = 2.5\ m/s$

$a_{max} = 1.2\ m/s^2$ (up)

$j_{max} = 2.5\ m/s^3$

elementary formulas

$v = \frac{dS}{dt}$ $a = \frac{dv}{dt}$ $j = \frac{da}{dt}$

Position in case of uniform acceleration:

$S_t = S_0 + v_0 t + \frac{1}{2} a_0 t^2$

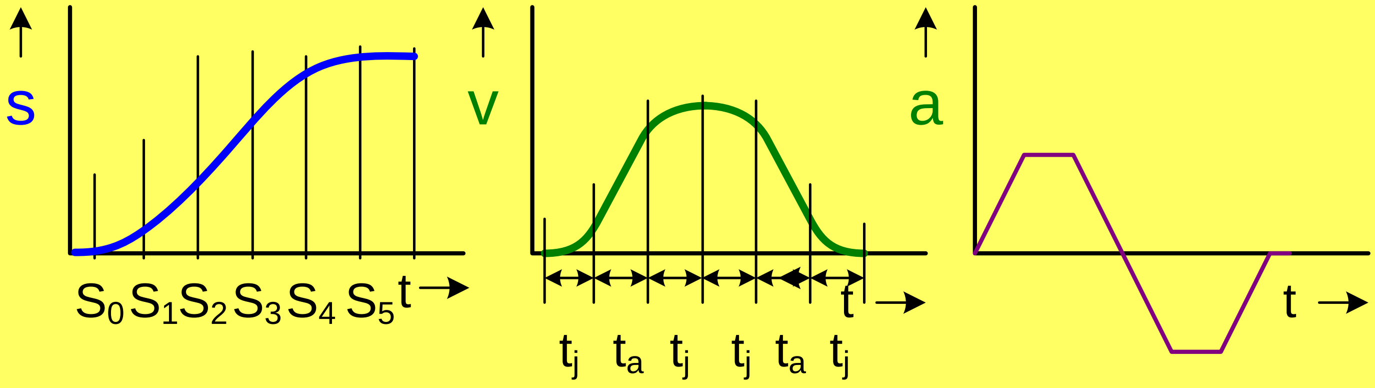
exercise

Make a model for $t_{one\ floor}$ and calculate it

What do you conclude from this model?

2nd Order Model Moving One Floor

2^{nd} order model



input data

S_0 = 0m

$S_{one\ floor}$ = 3m

v_{max} = 2.5 m/s

a_{max} = 1.2 m/s^2 (up)

j_{max} = 2.5 m/s^3

$t_{one\ floor} = 2\ t_a + 4\ t_j$

$t_j = a_{max} / j_{max}$

$S_1 = 1/6 * j_{max}\, t_j^3$

$v_1 = 0.5\ j_{max}\, t_j^2$

$S_2 = S_1 + v_1 t_a + 0.5\ a_{max} t_a^2$

$v_2 = v_1 + a_{max}\, t_a$

$S_3 = S_2 + v_2 t_j + 0.5\ a_{max} t_j^2 - 1/6\ j_{max} t_j^3$

$S_3 = 0.5\ S_t$

t_j ~= 1.2/2.5 ~= 0.5s

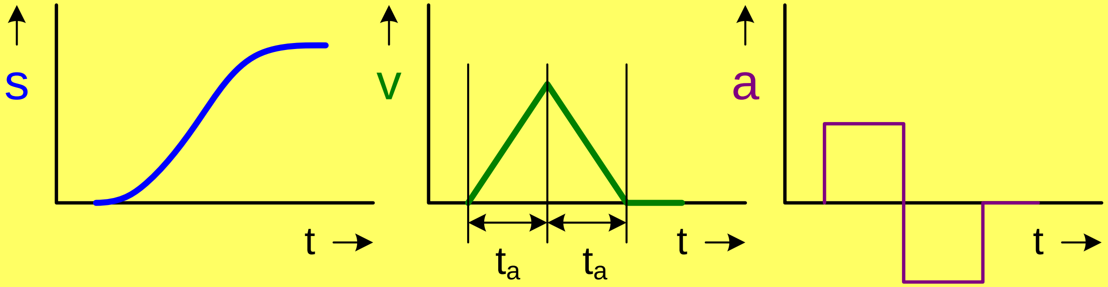
S_1 ~= 1/6 * 2.5 * 0.5^3 ~= 0.05m

v_1 ~= 0.5 * 2.5 * 0.5^2 ~= 0.3m/s

et cetera

1st Order Model Moving One Floor

1st order model



input data

S_0 = 0m $S_{one\ floor}$ = 3m

v_{max} = 2.5 m/s

a_{max} = 1.2 m/s^2 (up)

j_{max} = 2.5 m/s^3

$$S(t_a) = \frac{1}{2} * a_{max} * t_a^{\,2}$$

$$t_a = \sqrt{(\, S(t_a) / (0.5 * a_{max}))}$$

$$t_{one\ floor} = 2\ t_a = 2\sqrt{(\, S(t_a) / (0.5 * a_{max}))}$$

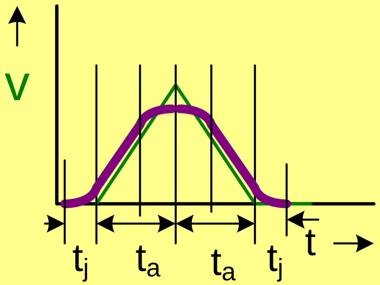
$v(t_a) = a_m t_a$ $v(t_a)$ ~= 1.2*1.6 ~= 1.9 m/s

$t_{one\ floor}$ ~=

$2\sqrt{(\, 1.5 / (0.5*1.2))}$ ~=

2 * 1.6s ~= **3s**

coarse 2nd order correction



$t_{one\ floor} = 2\ t_a + 2\ t_j$

t_j ~= 0.5s

$t_{one\ floor}$ ~= 2*1.6 + 2*0.5 ~= **4s**

Conclusions Move One Floor

Conclusions

a_{max} dominates travel time

The model for small height traveling time can be simplified into:

$$t_{travel} = 2 \sqrt{(S_{travel}/0.5\ a_{max})} + t_j$$

Exercise Elevator Performance

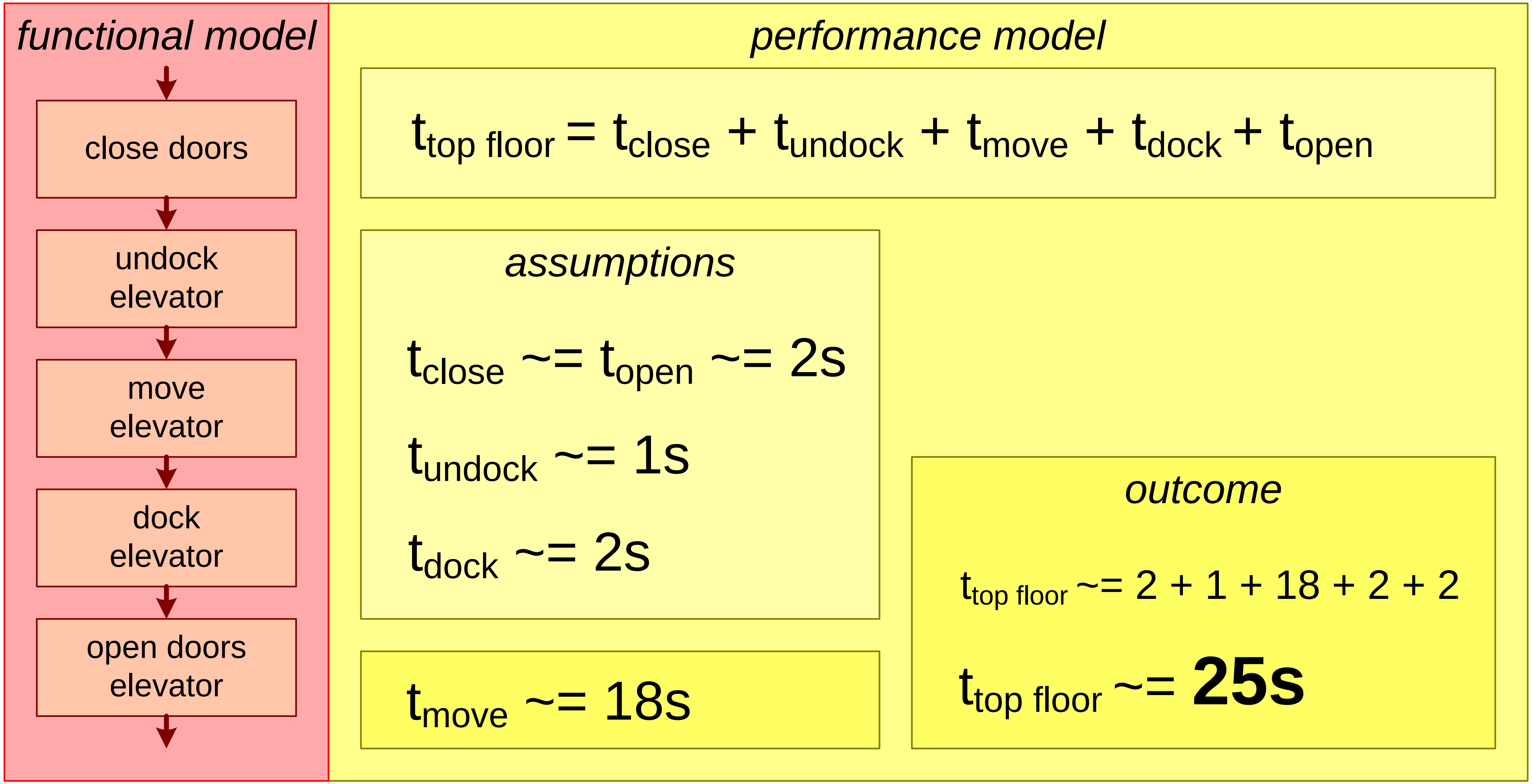
exercise

Make a model for $t_{top\ floor}$

Take door opening and docking into account

What do you conclude from this model?

Elevator Performance Model



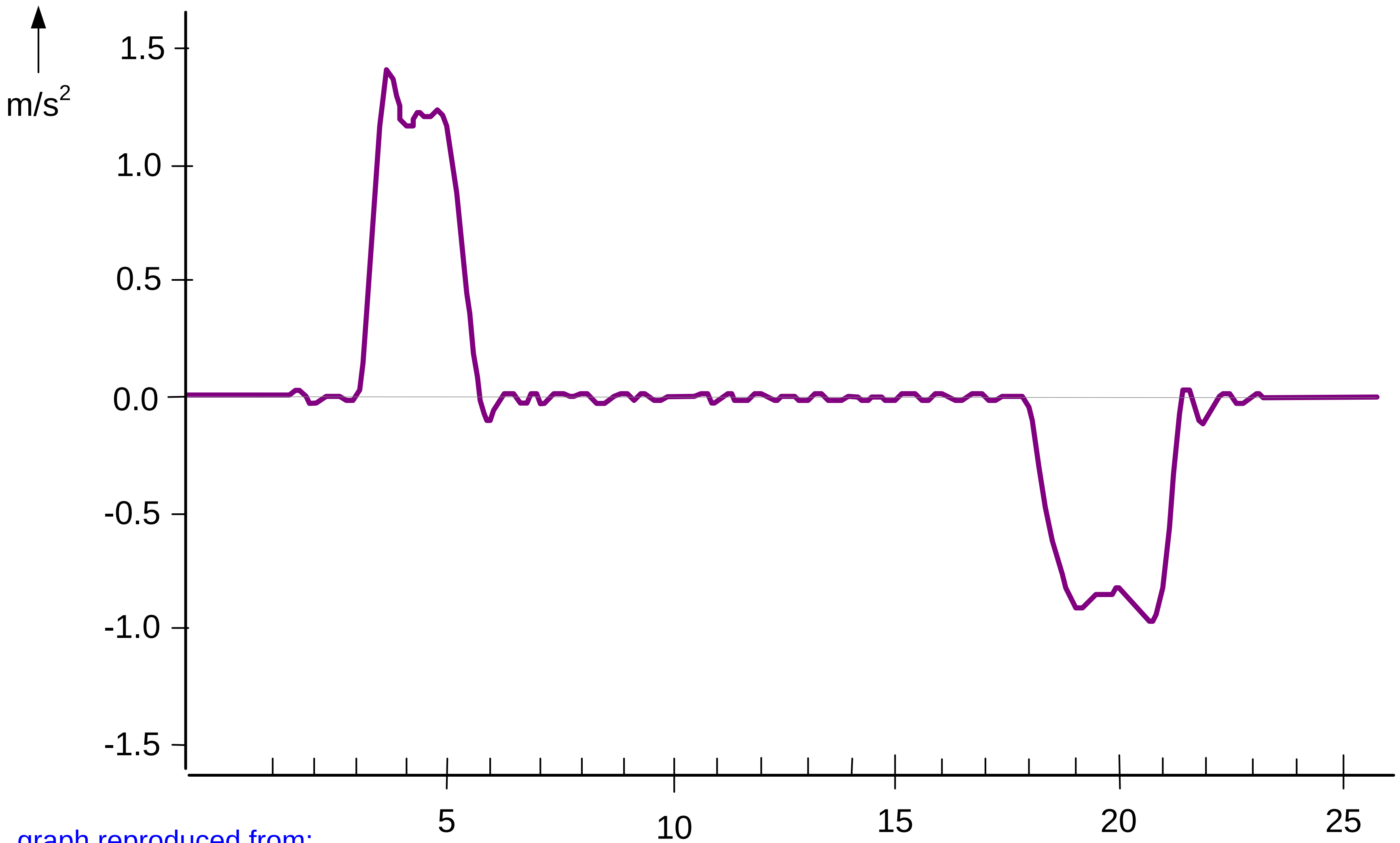
Conclusions

The time to move is dominating the traveling time.

Docking and door handling is significant part of the traveling time.

$t_{\text{top floor}} = t_{\text{travel}} + t_{\text{elevator overhead}}$

Measured Elevator Acceleration



graph reproduced from:
http://www.sensor123.com/vm_eva625.htm
CEP Instruments Pte Ltd Singapore

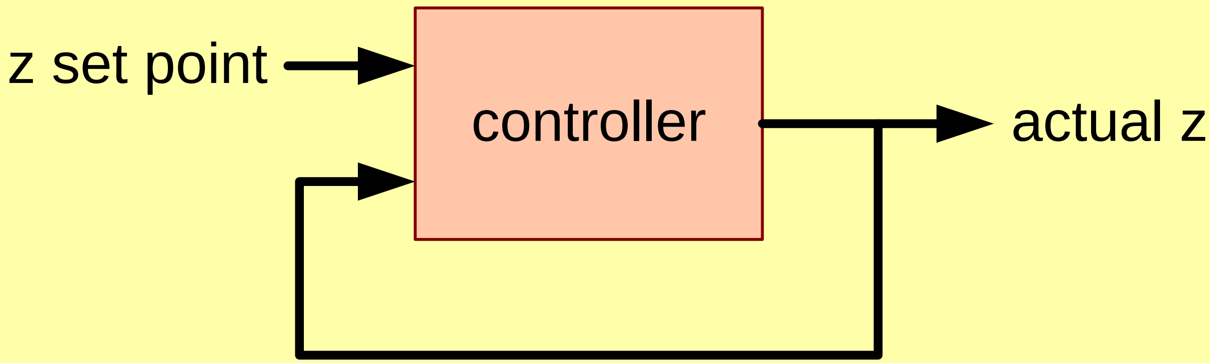
Theory versus Practice

What did we ignore or forget?

acceleration: up <> down 1.2 m/s^2 vs 1.0 m/s^2

slack, elasticity, damping et cetera of cables, motors....

controller impact



.....

Exercise Time to Travel One Floor

exercise

Make a model for $t_{one\ floor}$

Take door opening and docking into account

What do you conclude from this model?

Elevator Performance Model

functional model

close doors

undock elevator

move elevator

dock elevator

open doors elevator

performance model one floor (3m)

$$t_{\text{one floor}} = t_{\text{close}} + t_{\text{undock}} + t_{\text{move}} + t_{\text{dock}} + t_{\text{open}}$$

assumptions

$t_{\text{close}} \sim= t_{\text{open}} \sim= 2s$

$t_{\text{undock}} \sim= 1s$

$t_{\text{dock}} \sim= 2s$

$t_{\text{move}} \sim= 4s$

outcome

$t_{\text{one floor}} \sim= 2 + 1 + 4 + 2 + 2$

$t_{\text{one floor}} \sim= \mathbf{11\ s}$

Conclusions Performance Model One Floor

Conclusions

Overhead of docking and opening and closing doors is dominating traveling time.

Fast docking and fast door handling has significant impact on traveling time.

$t_{\text{one floor}} = t_{\text{travel}} + t_{\text{elevator overhead}}$

Exercise Time Line

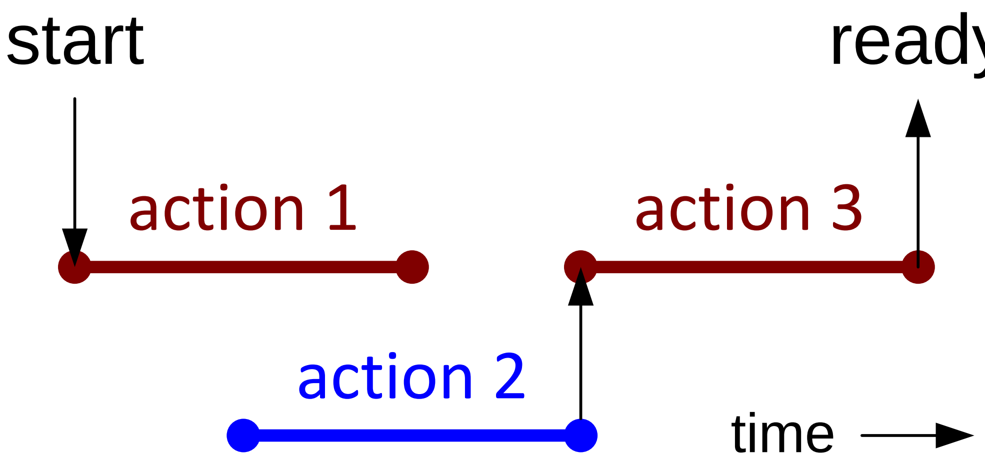
Exercise

Make a time line of people using the elevator.

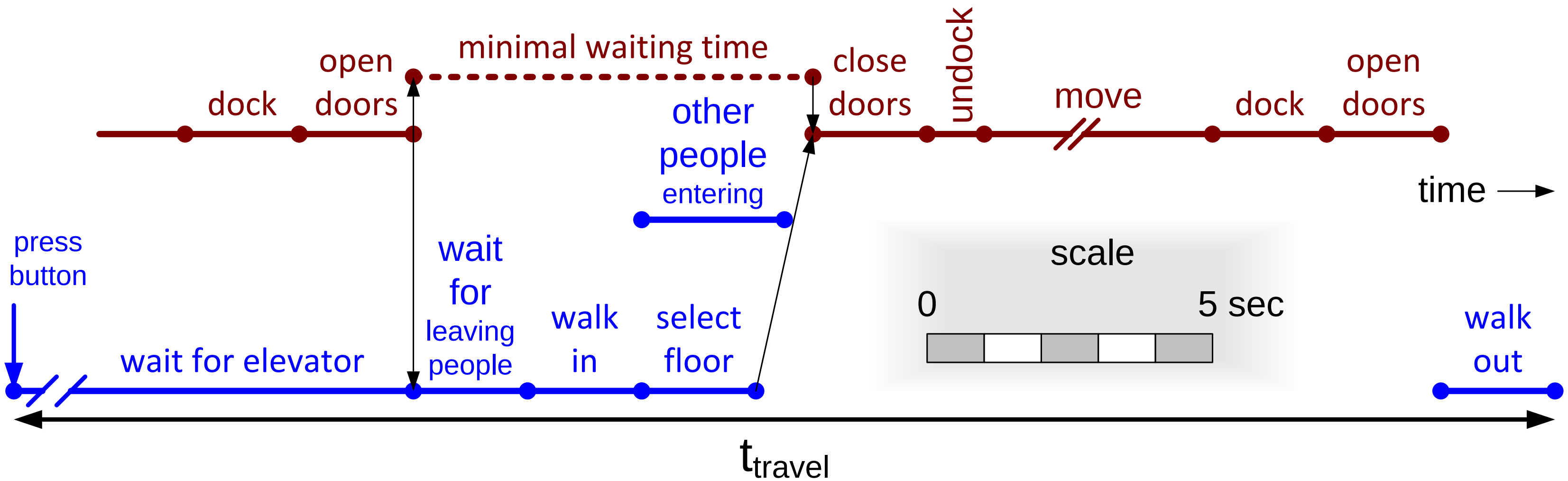
Estimate the time needed to travel to the top floor.

Estimate the time needed to travel one floor.

What do you conclude?



Time Line; Humans Using the Elevator



assumptions human dependent data

$t_{wait\ for\ elevator}$ = [0..2 minutes] depends heavily on use

$t_{wait\ for\ leaving\ people}$ = [0..20 seconds] idem

$t_{walk\ in}$ ~= $t_{walk\ out}$ ~= 2 s

$t_{select\ floor}$ ~= 2 s

assumptions additional elevator data

$t_{minimal\ waiting\ time}$ ~= 8s

$t_{travel\ top\ floor}$ ~= 25s

$t_{travel\ one\ floor}$ ~= 11s

outcome

$t_{one\ floor} = t_{minimal\ waiting\ time} + t_{walk\ out} + t_{travel\ one\ floor} + t_{wait}$

$t_{top\ floor} = t_{minimal\ waiting\ time} + t_{walk\ out} + t_{travel\ top\ floor} + t_{wait}$

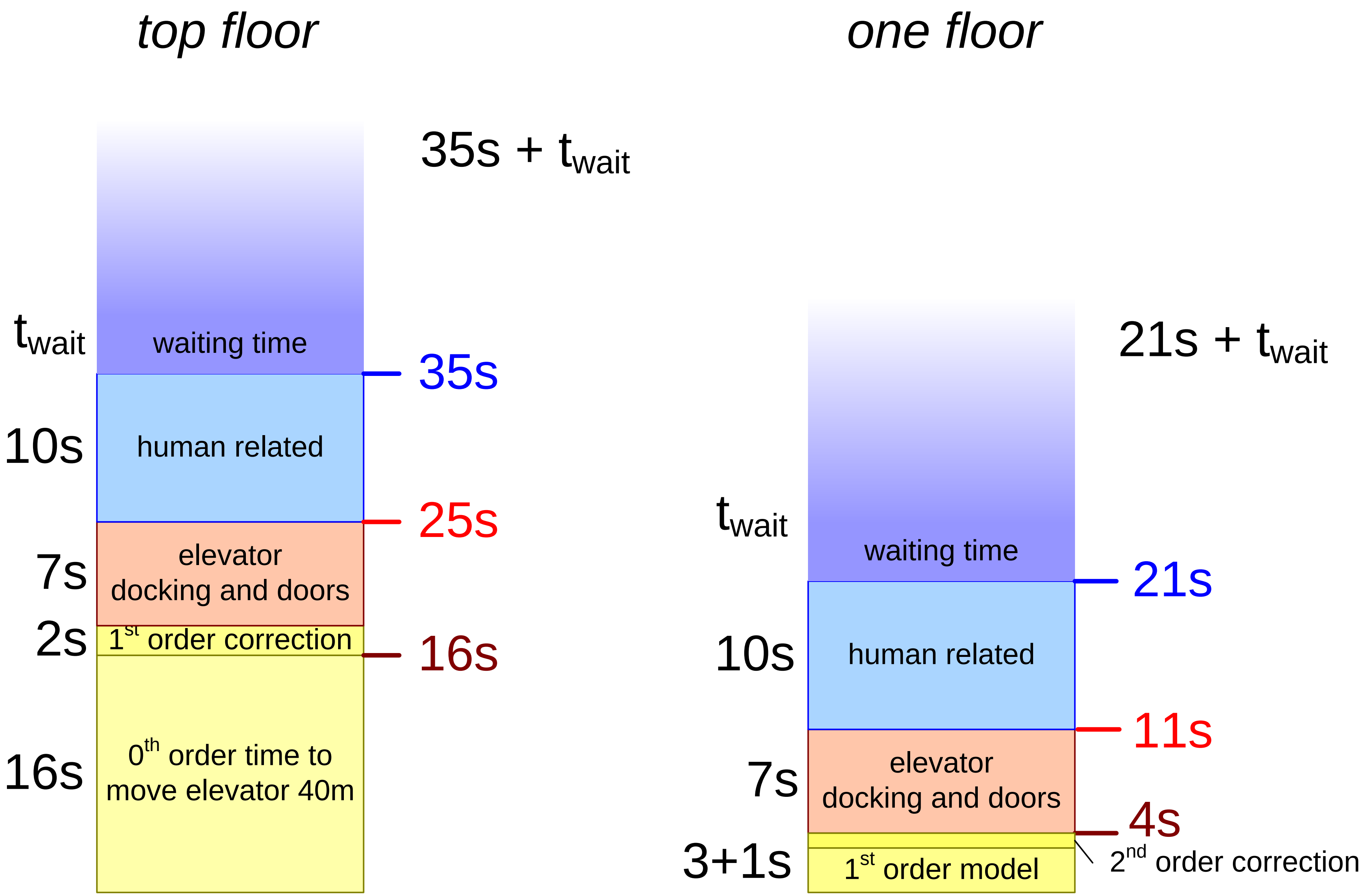
$t_{one\ floor}$ ~= 8 +2 + 11 + t_{wait}

~= **21 s** + t_{wait}

$t_{top\ floor}$ ~= 8 +2 + 25 + t_{wait}

~= **35 s**+ t_{wait}

Overview of Results for One Elevator



Conclusions

The human related activities have significant impact on the end-to-end time.

The waiting times have significant impact on the end-to-end time and may vary quite a lot.

$$t_{\text{end-to-end}} = t_{\text{human activities}} + t_{\text{wait}} + t_{\text{elevator travel}}$$

Exercise Energy and Power

Exercise

Estimate the energy consumption and the average and peak power needed to travel to the top floor.

What do you conclude?

Energy and Power Model

input data

S_0 = 0m

S_t = 40m

v_{max} = 2.5 m/s

$m_{elevator}$ = 1000 Kg (incl counter weight)

a_{max} = 1.2 m/s^2 (up)

$m_{passenger}$ = 100 Kg

j_{max} = 2.5 m/s^3

1 passenger going up

g = 10 m/s^2

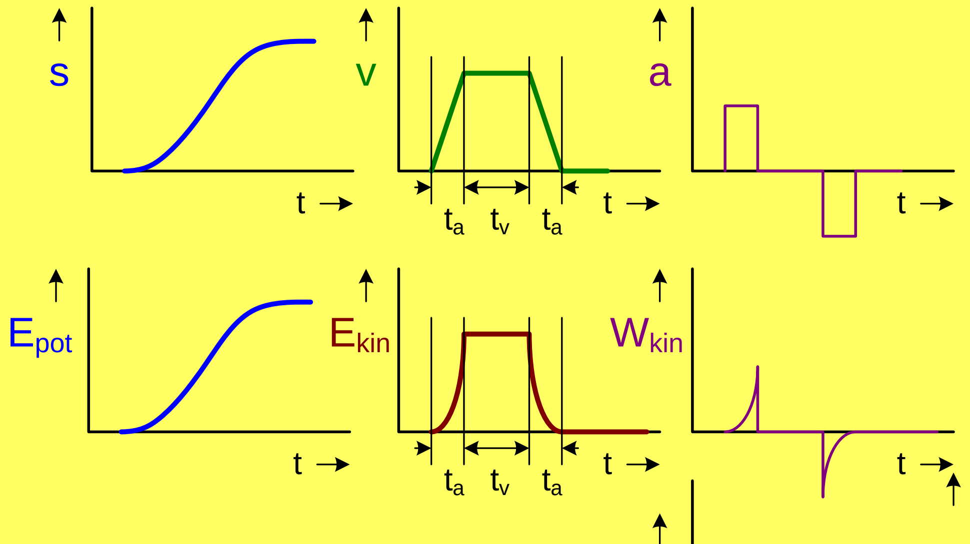
elementary formulas

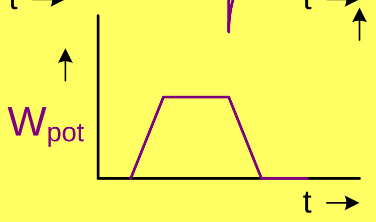
$E_{kin} = 1/2\ mv^2$

$E_{pot} = mgh$

$$W = \frac{dE}{dt}$$

1st order model





ignored:

friction and other losses

efficiency of energy transfer

$E_{kin\ max} = 1/2\ m\ v_{max}^2$

~= 0.5 * 1100 * 2.5^2

~= 3.4 kJ

$W_{kin\ max} = m\ v_{max}\ a_{max}$

~= 1100 * 2.5 * 1.2

~= 3.3 kW

$E_{pot} = mgh$

~= 100 * 10 * 40

~= 40 kJ

$W_{pot\ max}$ ~= E_{pot}/t_v

~= 40/16

~= 2.5 kW

Energy and Power Conclusions

Conclusions	
E_{pot} dominates energy balance	$E_{kin\ max} = 1/2\ m\ v_{max}^2$
	$\sim= 0.5 * 1100 * 2.5^2$
	$\sim=$ **3.4 kJ**
W_{pot} is dominated by v_{max}	$W_{kin\ max} = m\ v_{max}\ a_{max}$
	$\sim= 1100 * 2.5 * 1.2$
	$\sim=$ **3.3 kW**
W_{kin} causes peaks in power consumption and absorption	$E_{pot} = mgh$
	$\sim= 100 * 10 * 40$
	$\sim=$ **40 kJ**
W_{kin} is dominated by v_{max} and a_{max}	$W_{pot\ max} \sim= E_{pot}/t_v$
	$\sim= 40/16$
	$\sim=$ **2.5 kW**

Exercise Qualities and Design Considerations

Exercise

What other qualities and design considerations relate to the kinematic models?

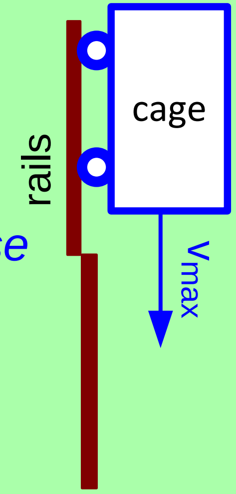
Examples of other qualities and design considerations

safety v_{max}

acoustic noise v_{max}, a_{max}, j_{max}

mechanical vibrations v_{max}, a_{max}, j_{max}

obstacles cause vibrations



air flow ?

operating life, maintenance duty cycle, ?

...

Other Domains

applicability in other domains

kinematic modeling can be applied in a wide range of domains:

- transportation systems (trains, busses, cars, containers, ...)
- wafer stepper stages
- health care equipment patient handling
- material handling (printers, inserters, ...)
- MRI scanners gradient generation
- ...

Exercise Multiple Users

Exercise

Assume that a group of people enters the elevator at the ground floor. On every floor one person leaves the elevator.

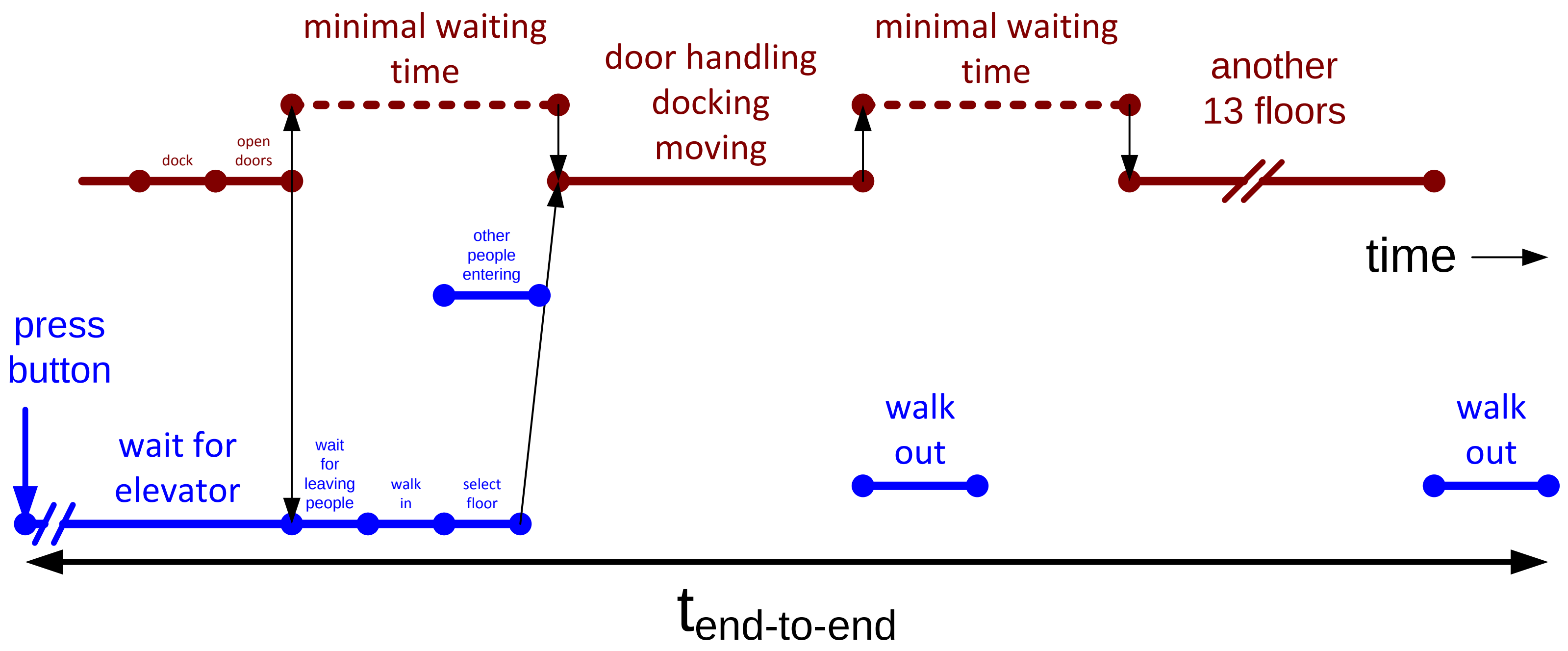
What is the end-to-end time for someone traveling to the top floor?

What is the desired end-to-end time?

What are potential solutions to achieve this?

What are the main parameters of the design space?

Multiple Users Model



elevator data

$t_{min\ wait}$ ~= 8s

$t_{one\ floor}$ ~= 11s

$t_{walk\ out}$ ~= 2s

n_{floors} = 40 div 3 +1 = 14

n_{stops} = n_{floors} – 1 = 13

outcome

$t_{end\text{-}to\text{-}end} = n_{stops}\ (t_{min\ wait} + t_{one\ floor}) + t_{walk\ out} + t_{wait}$

~= 13 * (8 + 11) + 2 + t_{wait}

~= **249 s** + t_{wait}

$t_{non\text{-}stop}$ ~= 35 s+ t_{wait}

Multiple Users Desired Performance

Considerations

desired time to travel to top floor ~< 1 minute

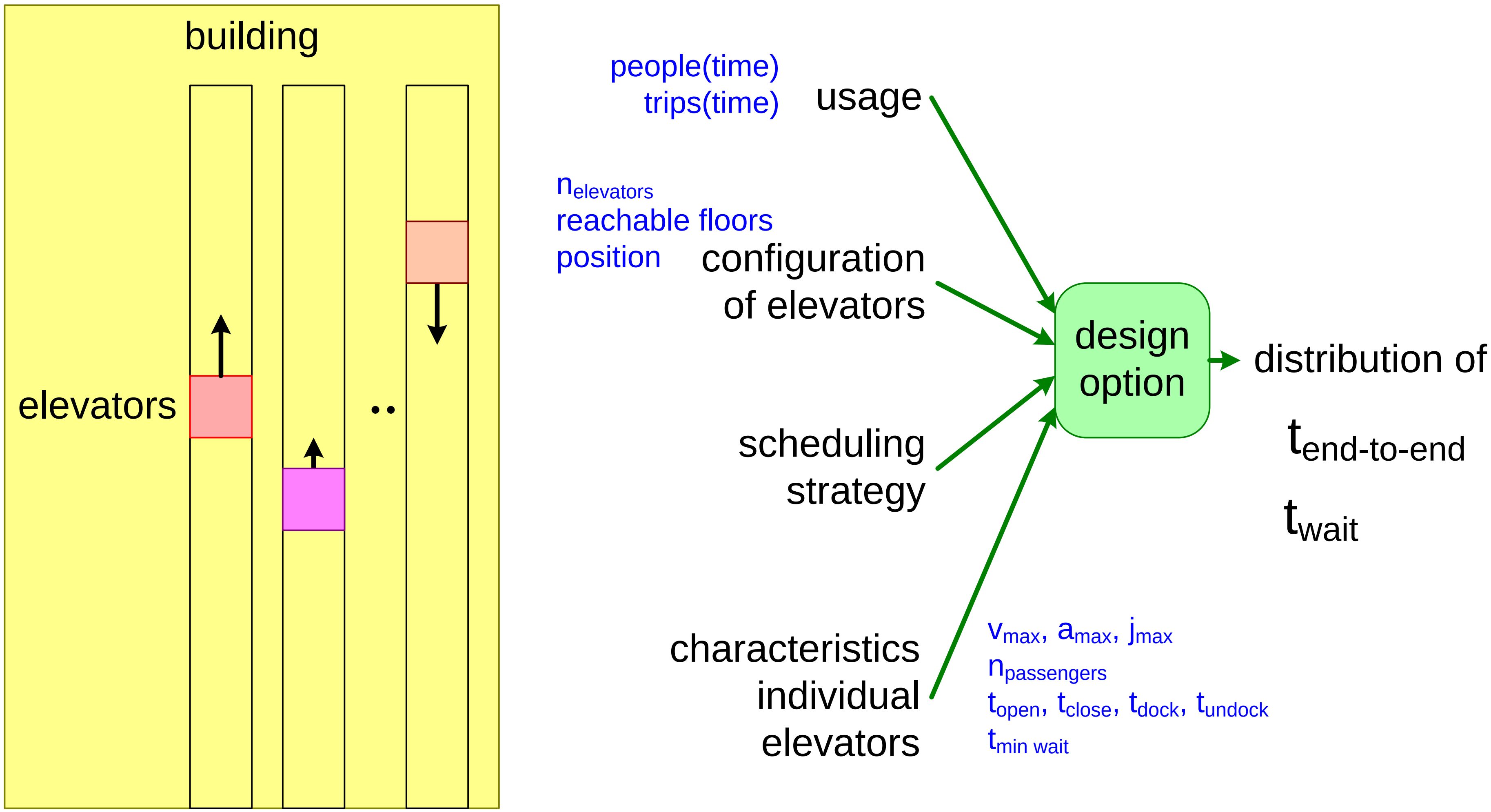
note that $t_{\text{wait next}} = t_{\text{travel up}} + t_{\text{travel down}}$

if someone just misses the elevator then the waiting time is

$t_{\text{end-to-end}} \sim= \underbrace{249}_{\text{missed trip}} + \underbrace{35}_{\text{return down}} + \underbrace{249}_{\text{trip up}} = 533\text{s} \sim= 9$ minutes!

desired waiting time ~< 1 minute

Design of Elevators System



Design of a system with multiple elevator requires a different kind of models: oriented towards logistics

Exceptional Cases

Exceptional Cases

non-functioning elevator

maintenance, cleaning of elevator

elevator used by people moving household

rush hour

special events (e.g. party, new years eve)

special floors (e.g. restaurant)

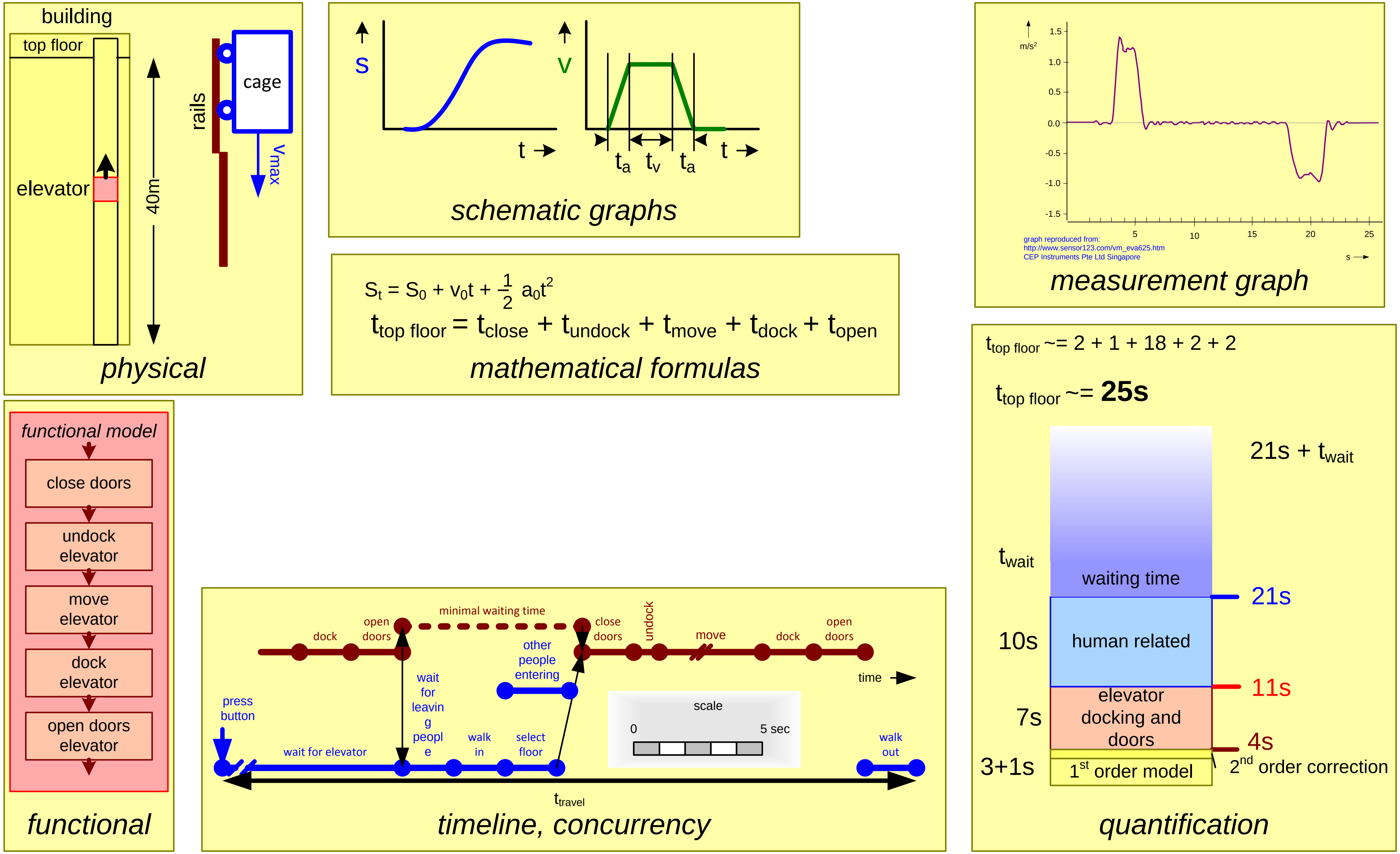
many elderly or handicapped people

playing children

Wrap-up Exercise

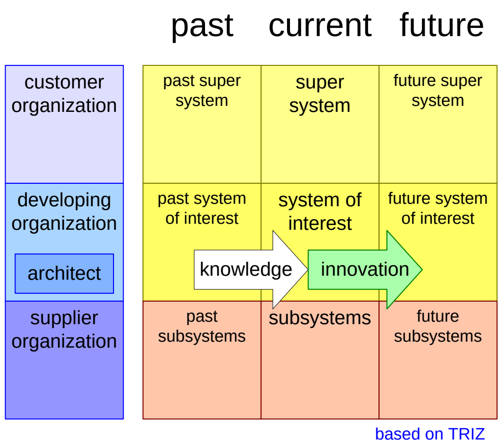
Make a list of all *visualizations* and *representations* that we used during the exercises

Summary of Visualizations and Representations

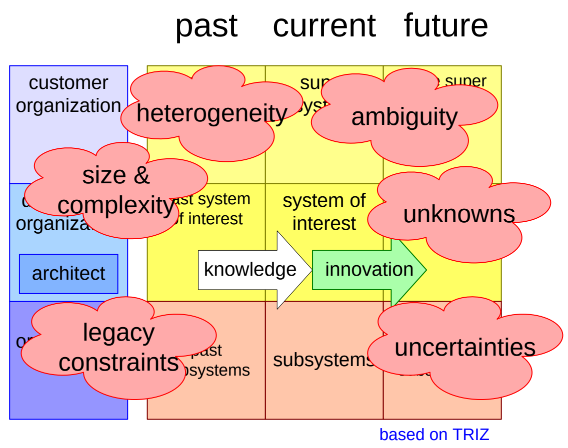


Architecting Scope and Challenges

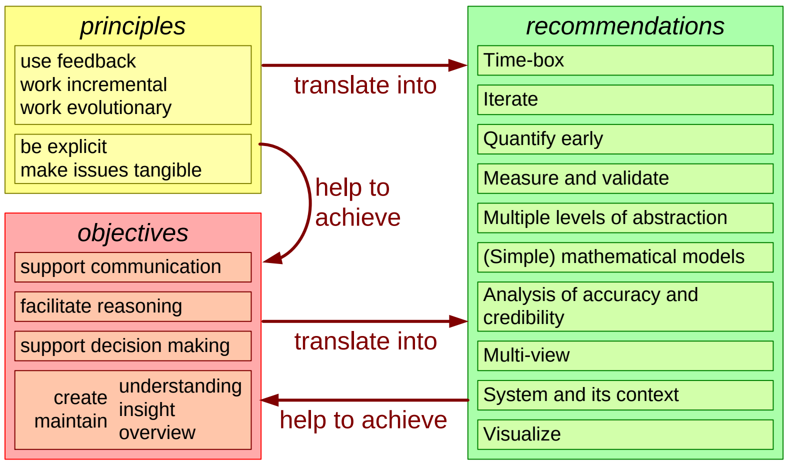
Scope



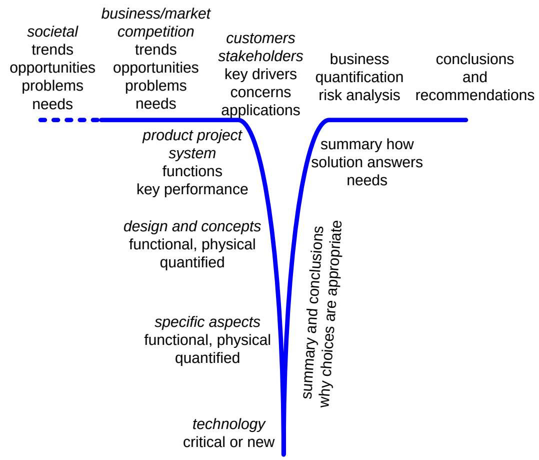
Challenges



Recommendations

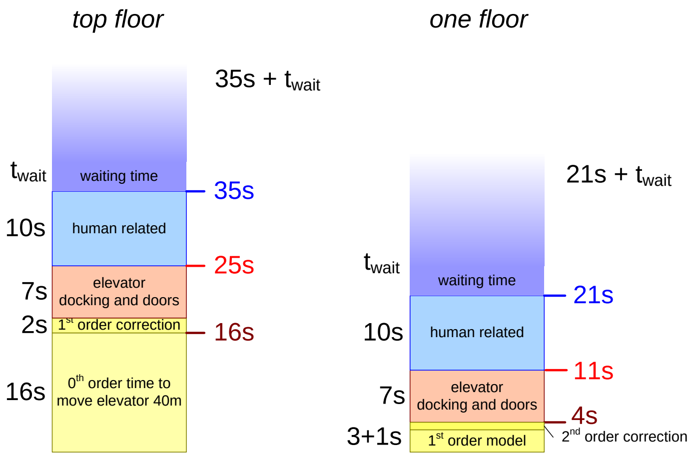


Final Top-Down Delivery

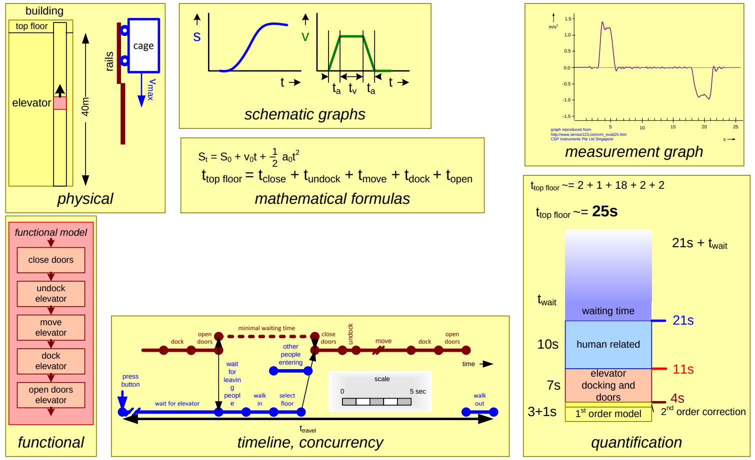


Introduction Conceptual Modeling

Zooming Out



Complementary Visualizations and Representations



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Module 31, Architectural Reasoning Case Exploration

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

This module introduces the case exploration used in the course Architectural Reasoning using Conceptual Modeling.

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status: preliminary draft
version: 1.0

SEMA Methods Overview

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

This presentation provides an overview of the SEMA course: Architectural Reasoning Using Conceptual Modeling. This course uses the CAFCR+ model with 6 views. Qualities connect all views. Threads-of-reasoning capture the architectural reasoning across views and qualities. Conceptual models visualize and capture the context, the system and its design. Quantification is a means to make problem and solution space tangible.

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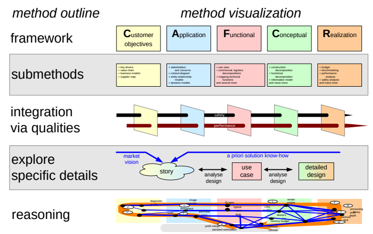
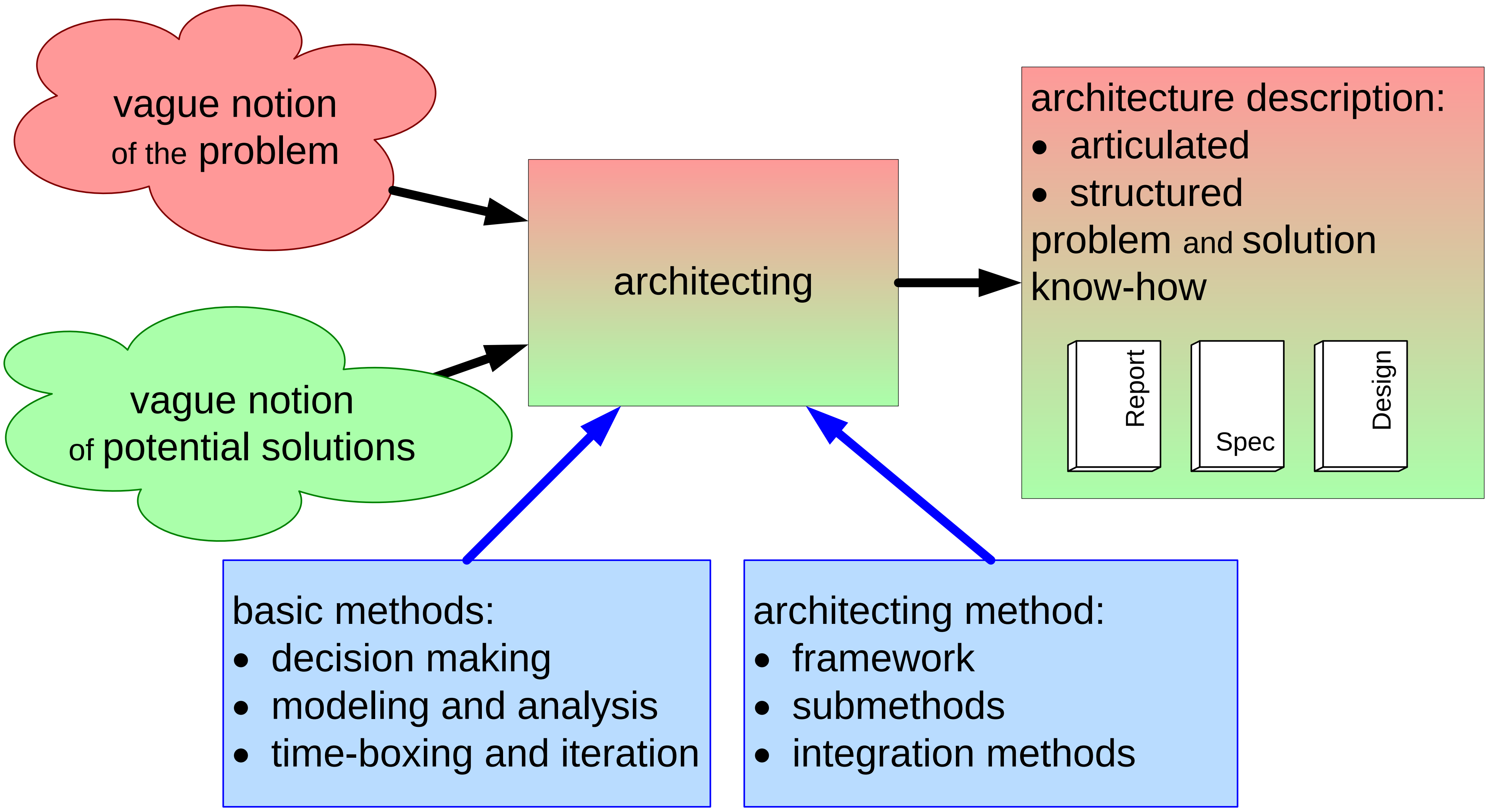
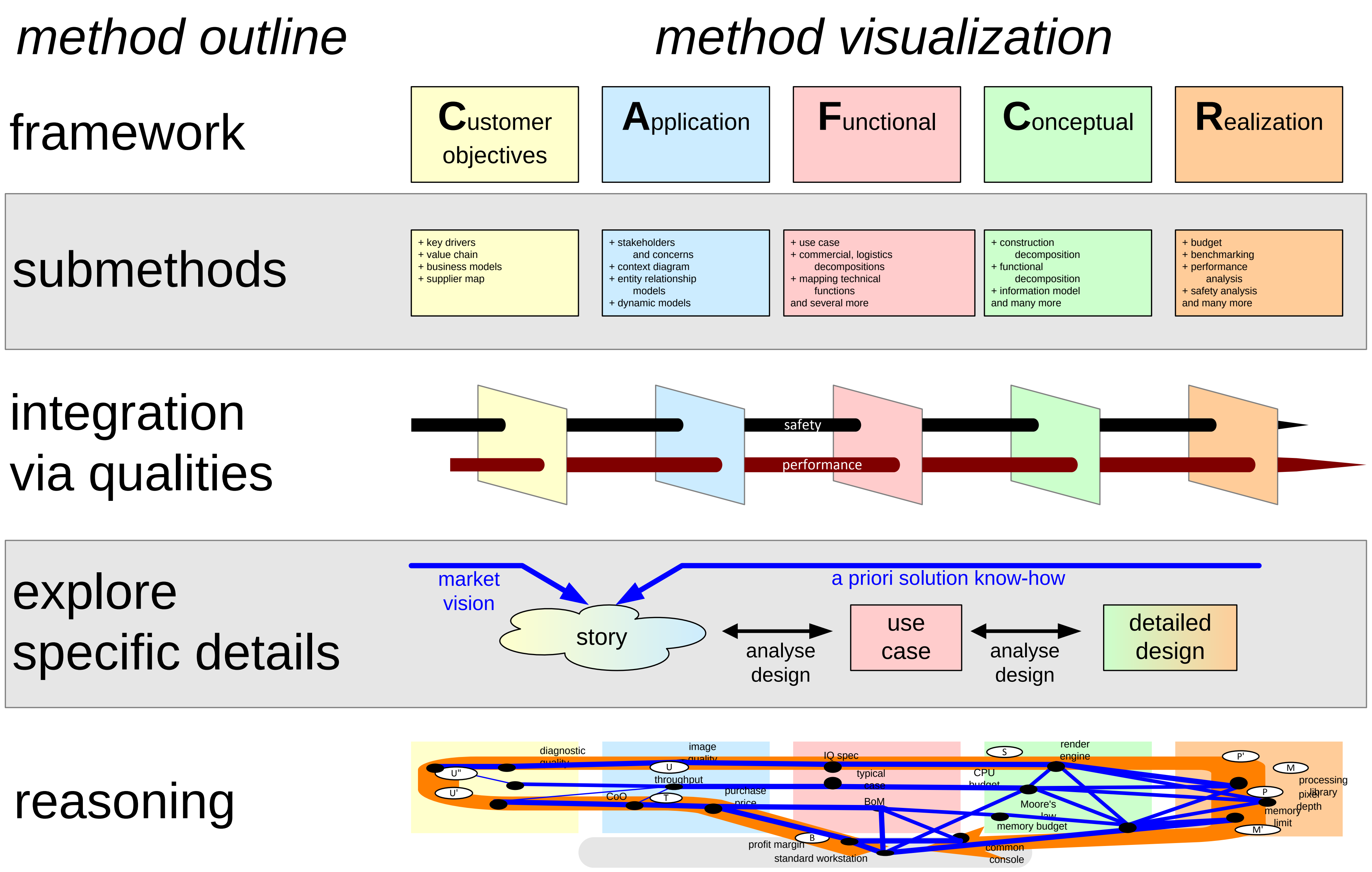


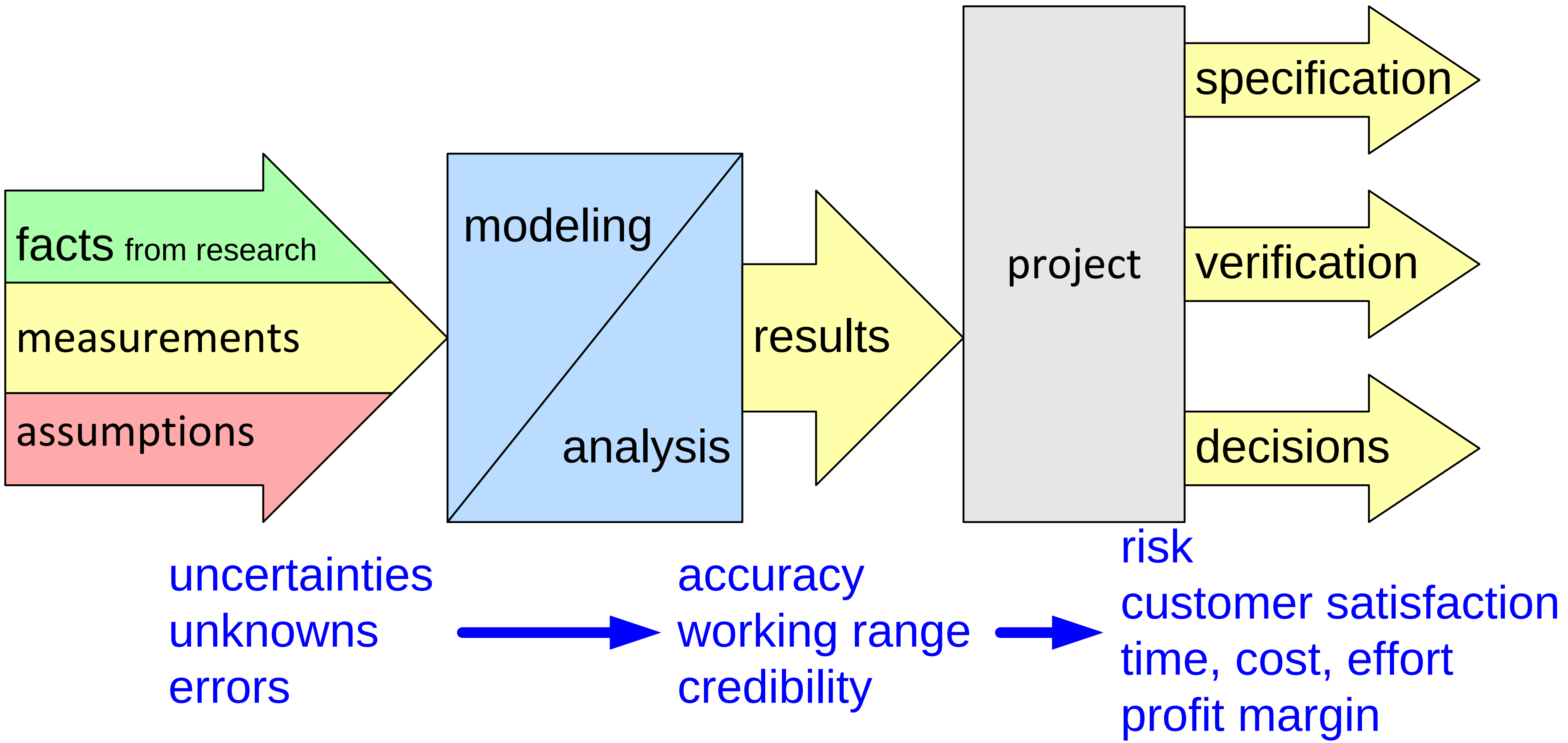
From vague notions to articulate and structured



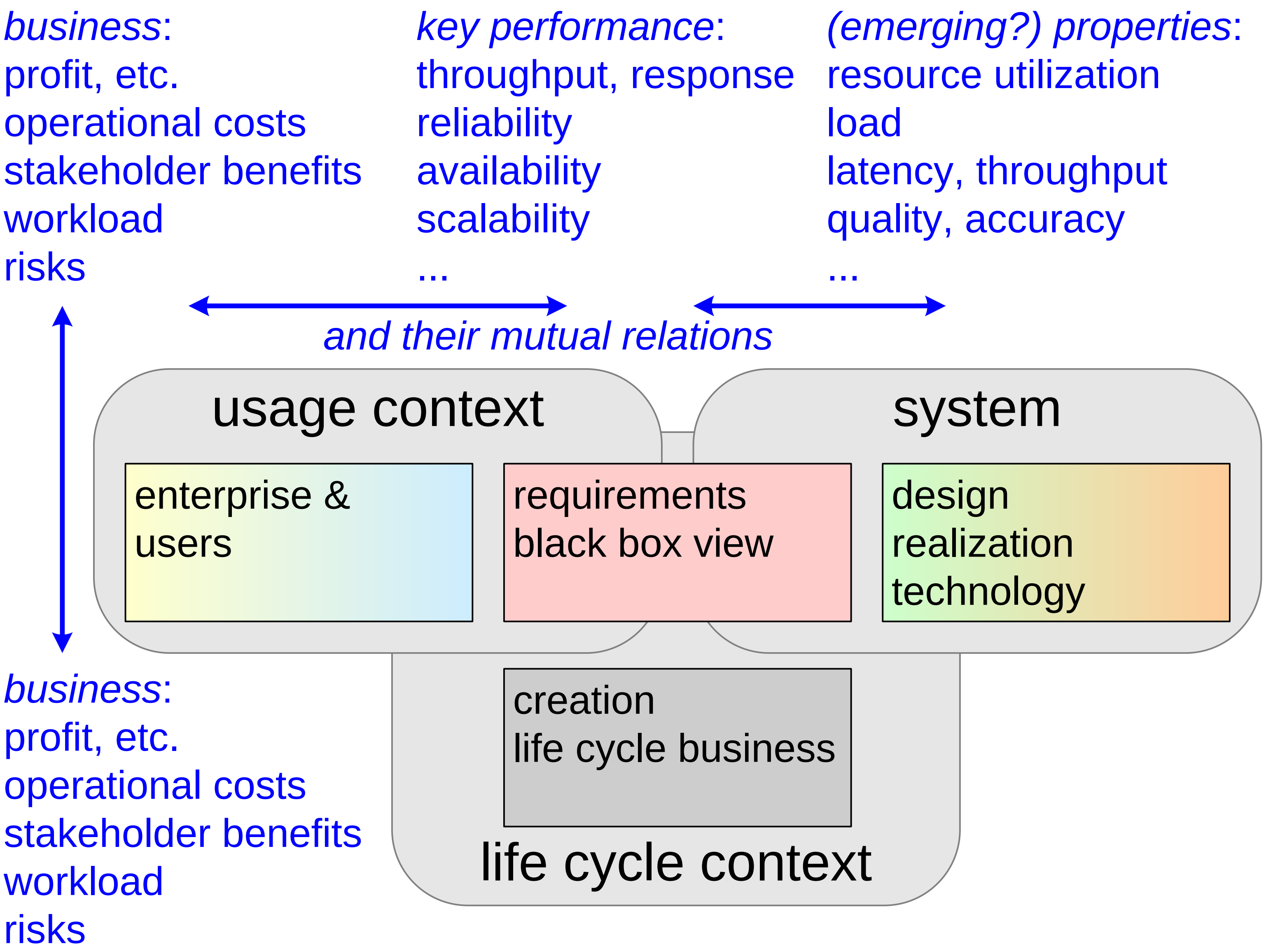
Overview of architecting method



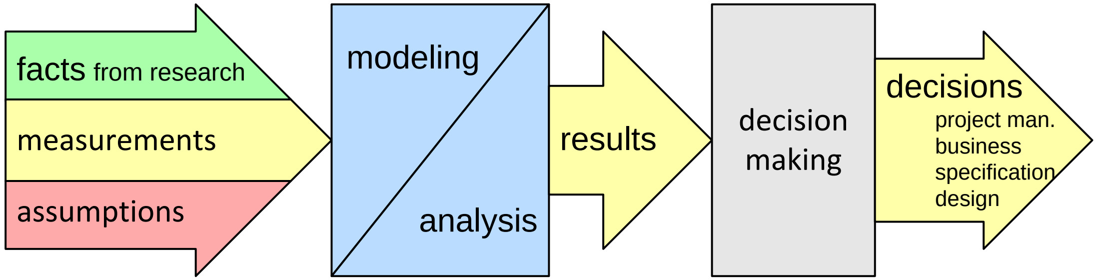
Purpose of Modeling



What to Model?

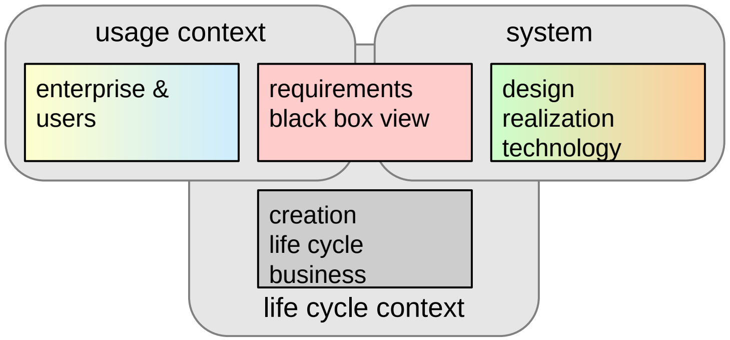


Overview of Modeling Approach



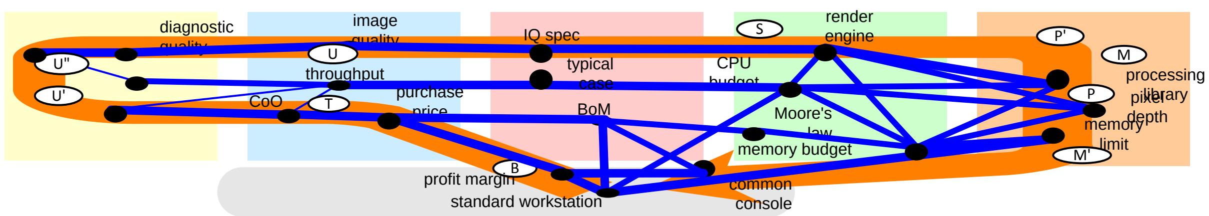
collect input data

model and analyse relevant issues



for different stakeholders& concerns

integration and reasoning



Short introduction to basic “CAFCR” model

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

The basic “CAFCR” reference model is described, which is used to describe a system in relation to its context. The main stakeholder in the context is the customer. The question “Who is the customer?” is addressed.

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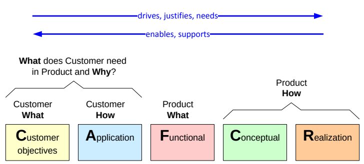
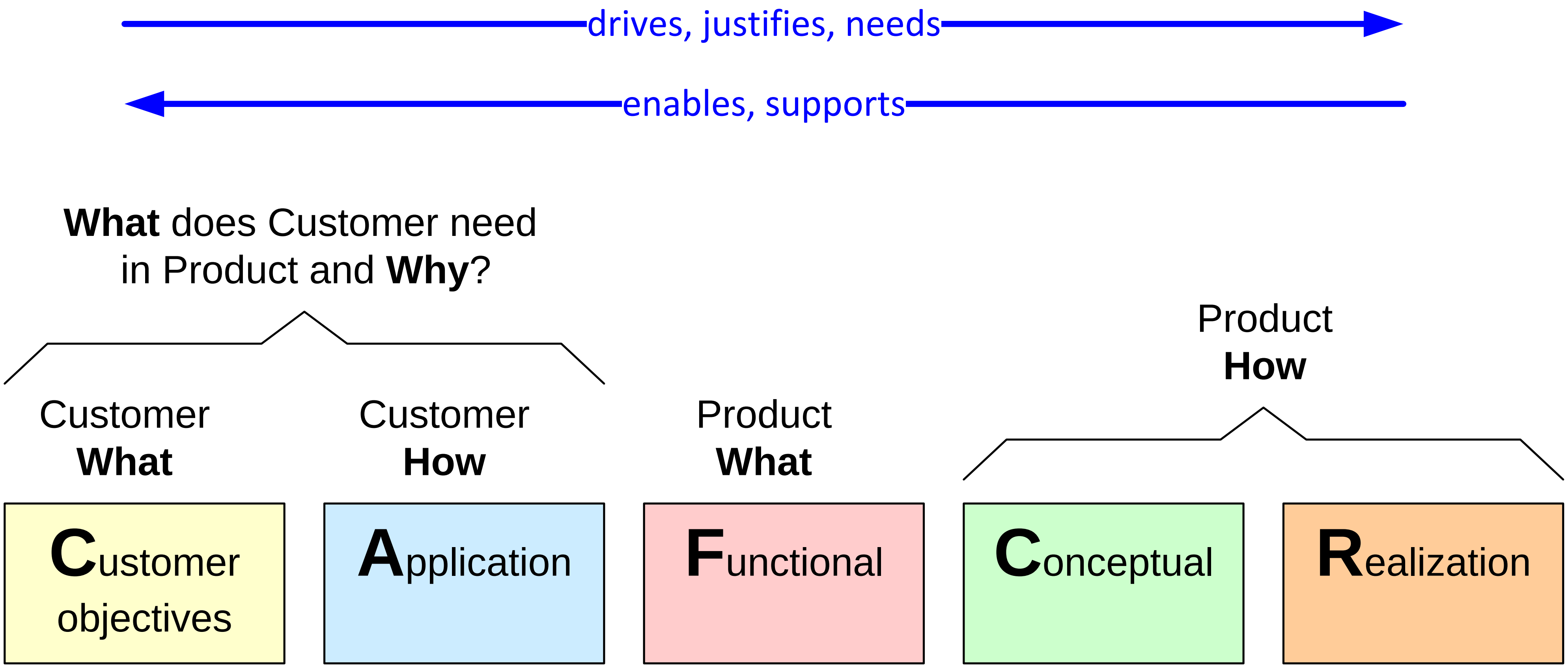
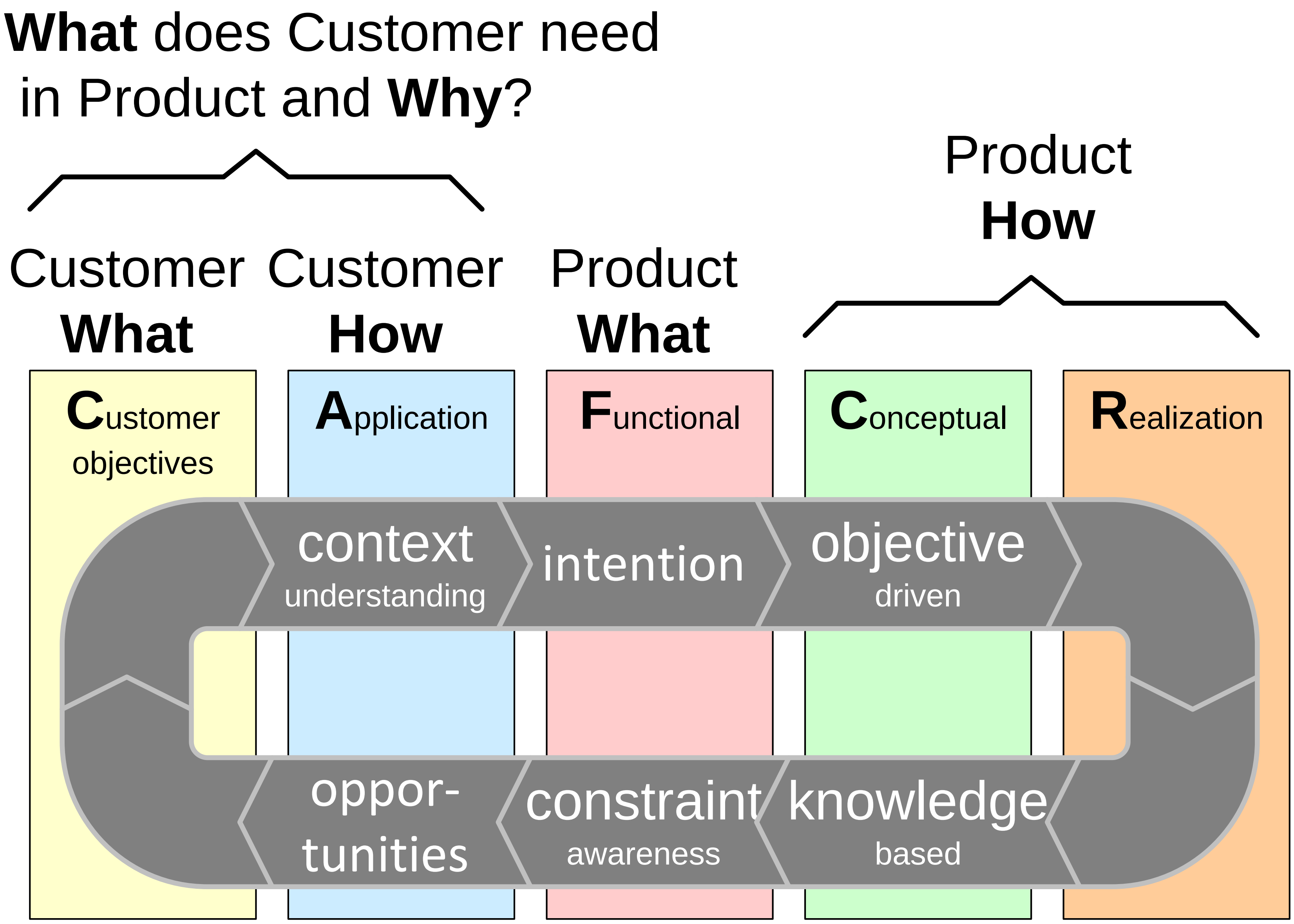


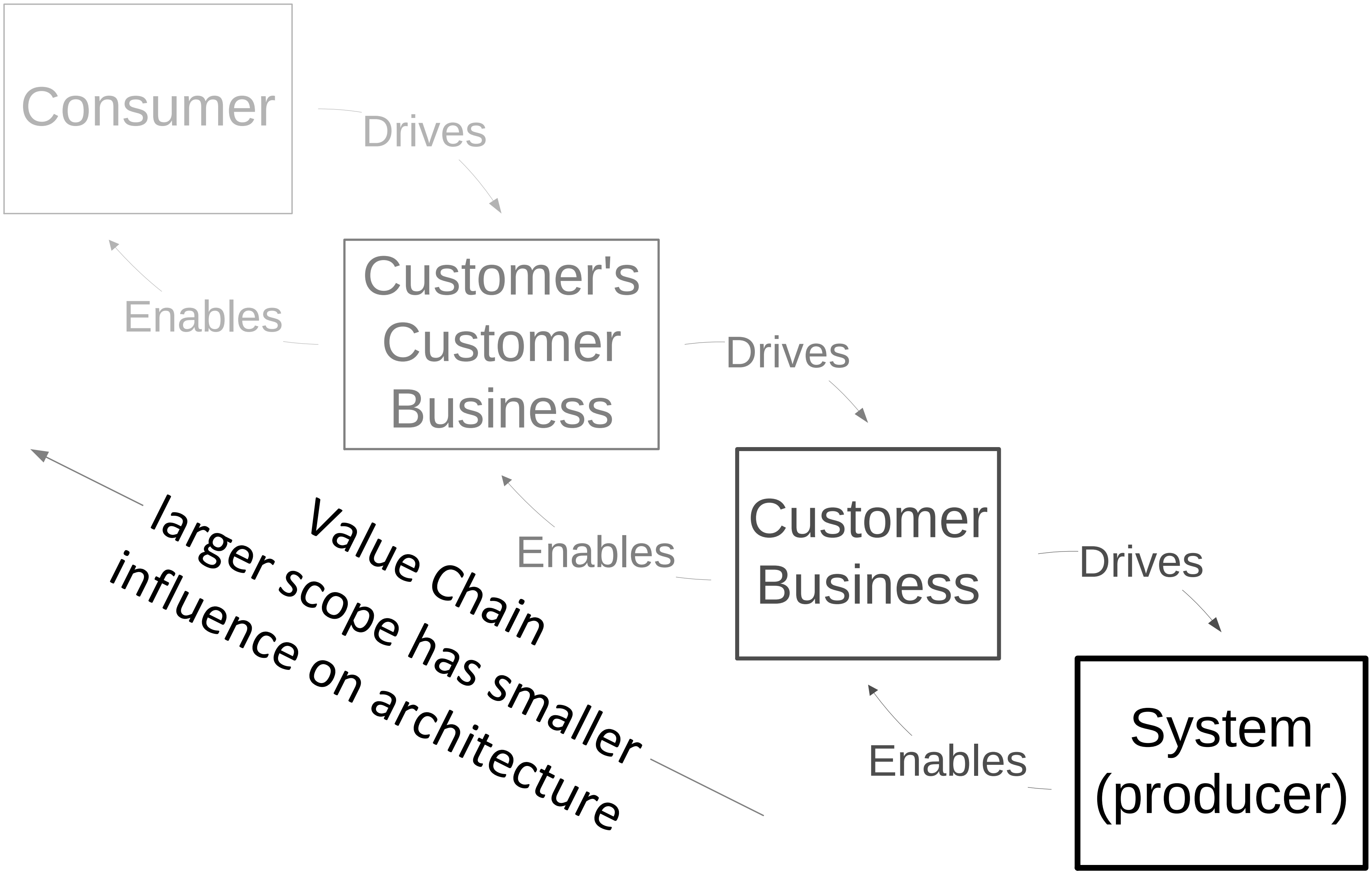
The “CAFCR” model



Integrating CAFCR



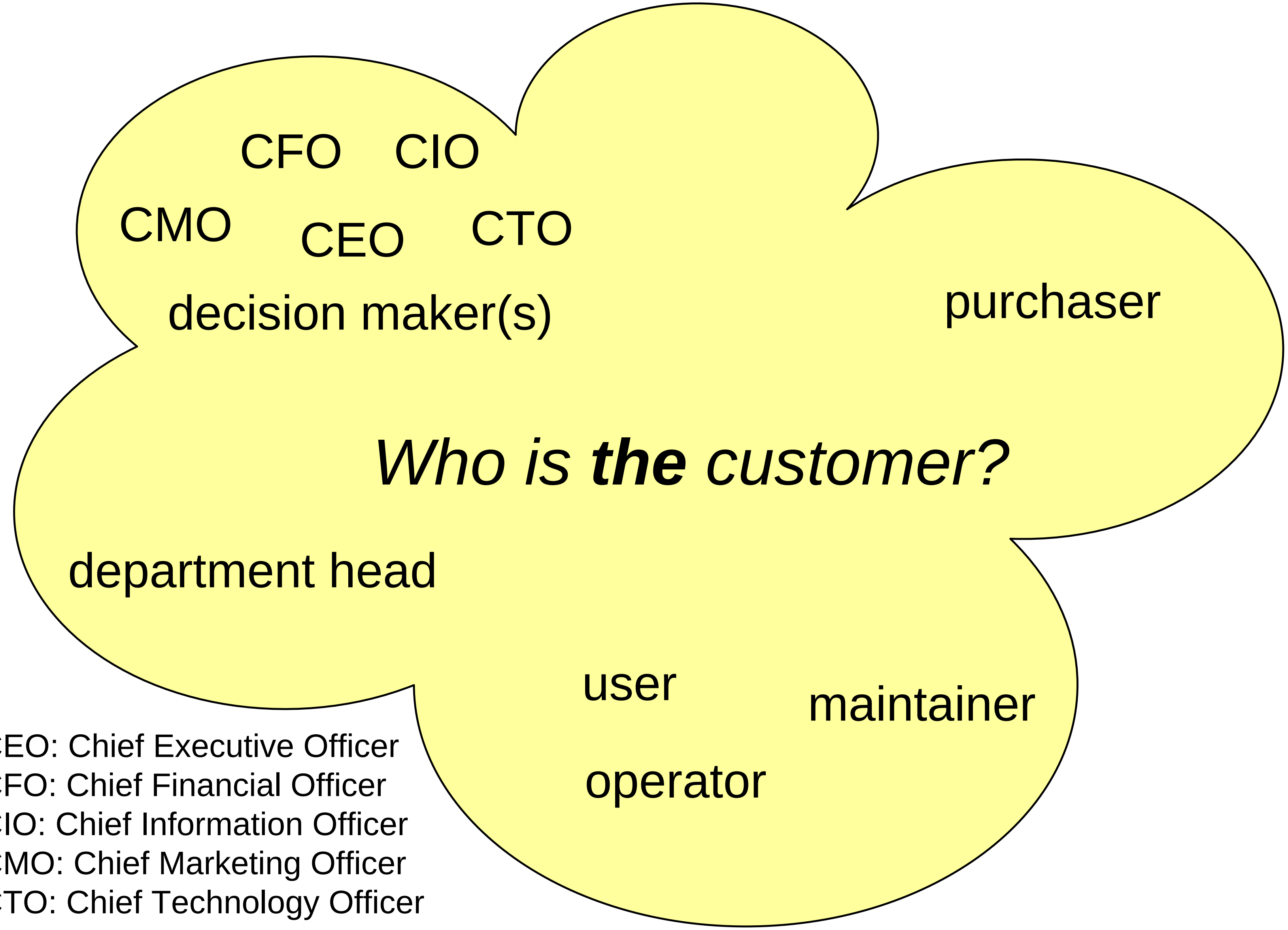
CAFCR can be applied recursively



Market segmentation

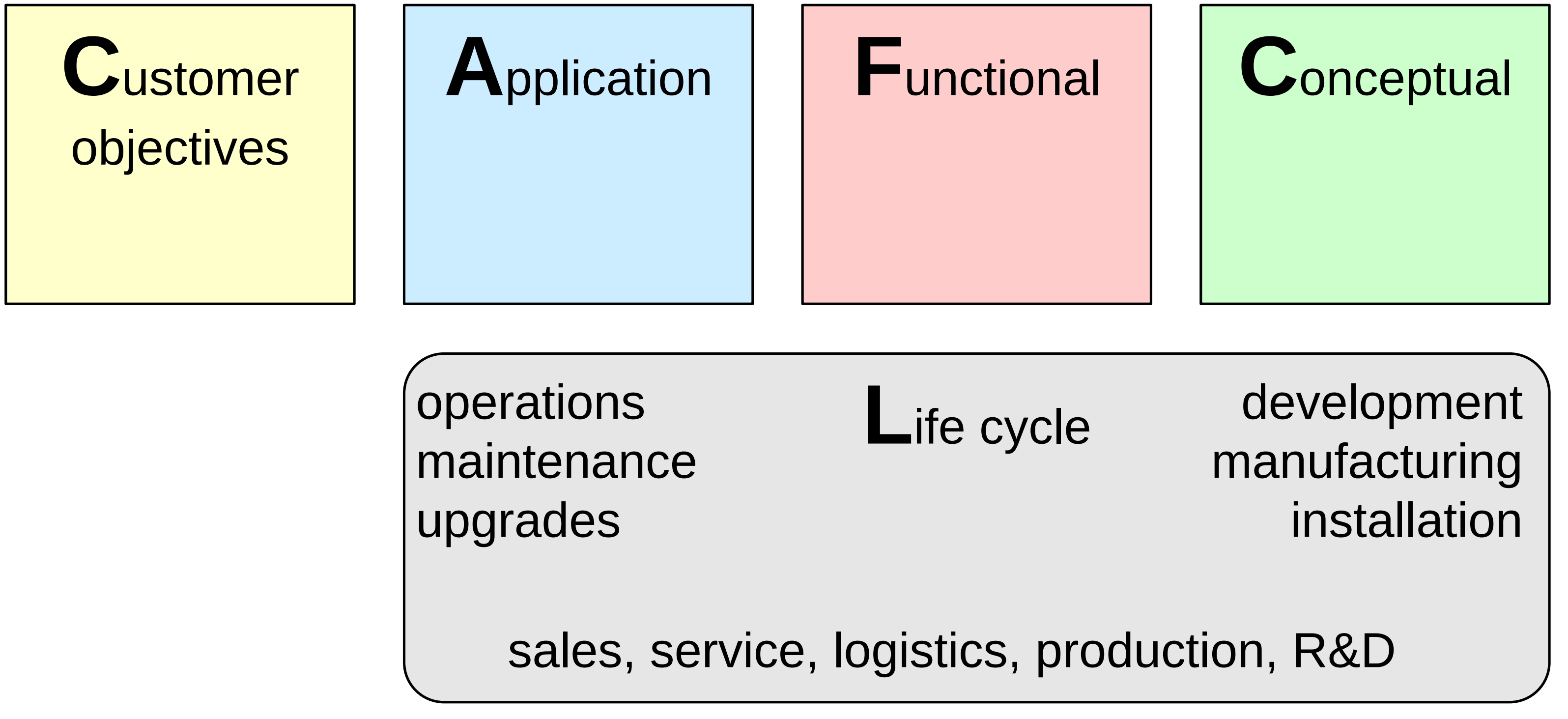
segmentation axis	examples
geographical	USA, UK, Germany, Japan, China
business model	profit, non profit
economics	high end versus cost constrained
consumers	youth, elderly
outlet	retailer, provider, OEM, consumer direct

Example of a small buying organization



CEO: Chief Executive Officer
CFO: Chief Financial Officer
CIO: Chief Information Officer
CMO: Chief Marketing Officer
CTO: Chief Technology Officer

CAFCR+ model; Life Cycle View



Initial CAFCR scan

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

This presentation guides a team through a quick CAFCR scan. Such quick scan with typically 15 minutes per view helps to build an initial overview of the problem and solution space.

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make a bottom-up analysis of your product:

1. realization
2. conceptual
3. functional
4. application
5. customer objectives
6. qualities

use time boxes of 15 minutes per view

show the most dominant decomposition of that view, as diagram or as a list; some more guidance will be given per step.

Exercise Bottom-up Scan CAFCR

make a bottom-up analysis of your product:

1. realization

2. conceptual

3. functional

4. application

5. customer objectives

6. qualities

use time boxes of 15 minutes per view

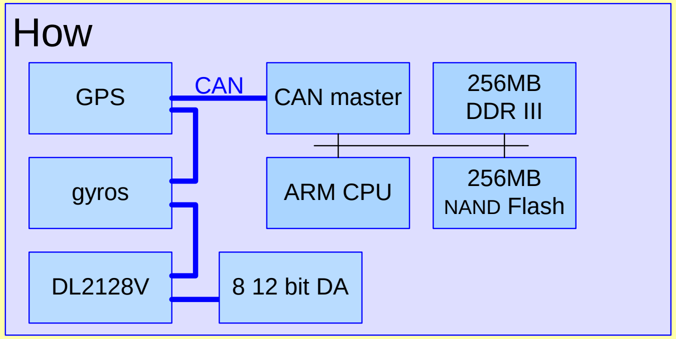
show the most dominant decomposition of that view, as diagram or as a list; some more guidance will be given per step.

Do and Don't

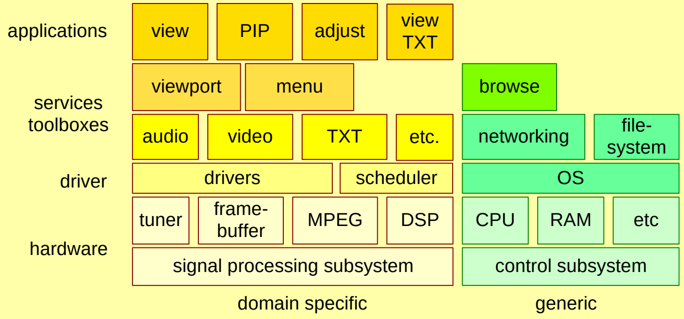
Do	Do **not**	Because
• start sketching/drawing as soon as possible	• write long texts .	• sketches stimulate sharing and discussion
• use shared large sheets of paper (e.g. flip-over)	• immediately capture electronic	• sharing and discussion help to explore faster
• number the flip-overs and add a title		• remembering the order gets challenging
• annotate (add notes) during discussions	• have nice but volatile discussions	• information and insight is quickly lost
• use yellow note stickers and flip-over markers	• write with pen or pencil	• stickers are easily (re)moved
• be open for ideas and surprises	• Do not stick to the first solution	• you hopefully discover a lot; increased insight will change problem and solution

Step 1: Realization View

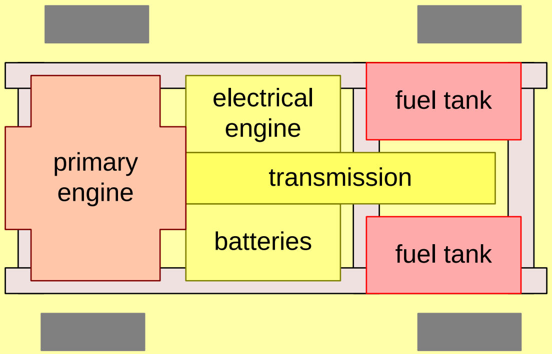
Choose 1 or 2 items from below



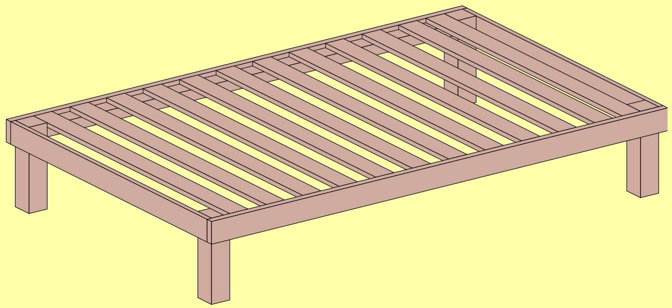
HW block diagram



SW layer diagram



2D layout of system internals

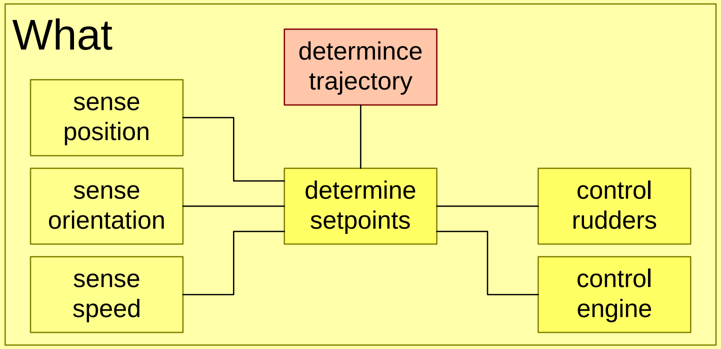


3D sketch of system internals

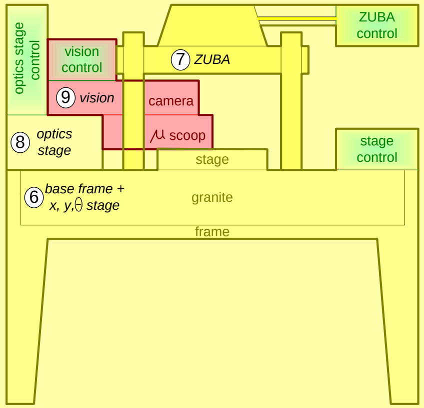
Annotate/mark most critical technologies or characteristics

Step 2: Conceptual View

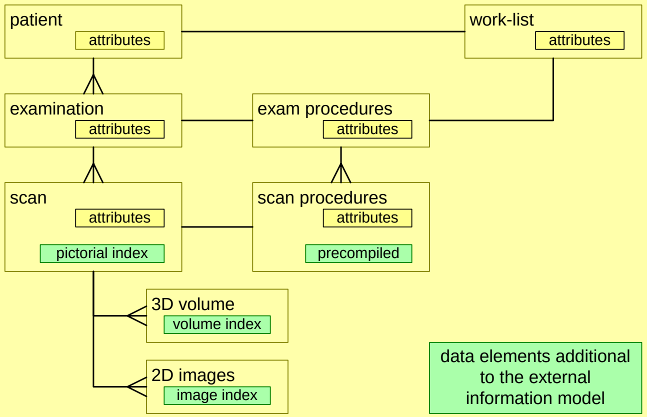
Chose 1 or 2 items from below



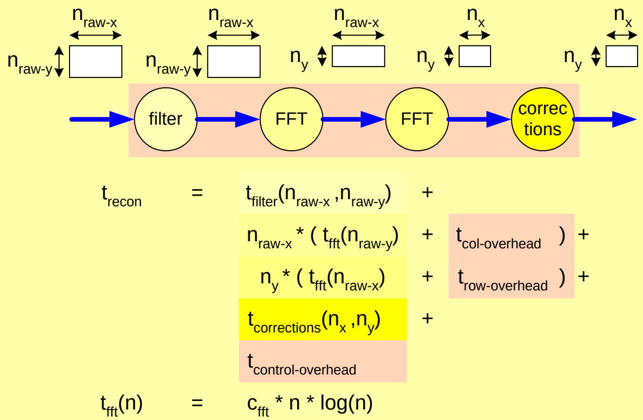
functional model



subsystem decomposition

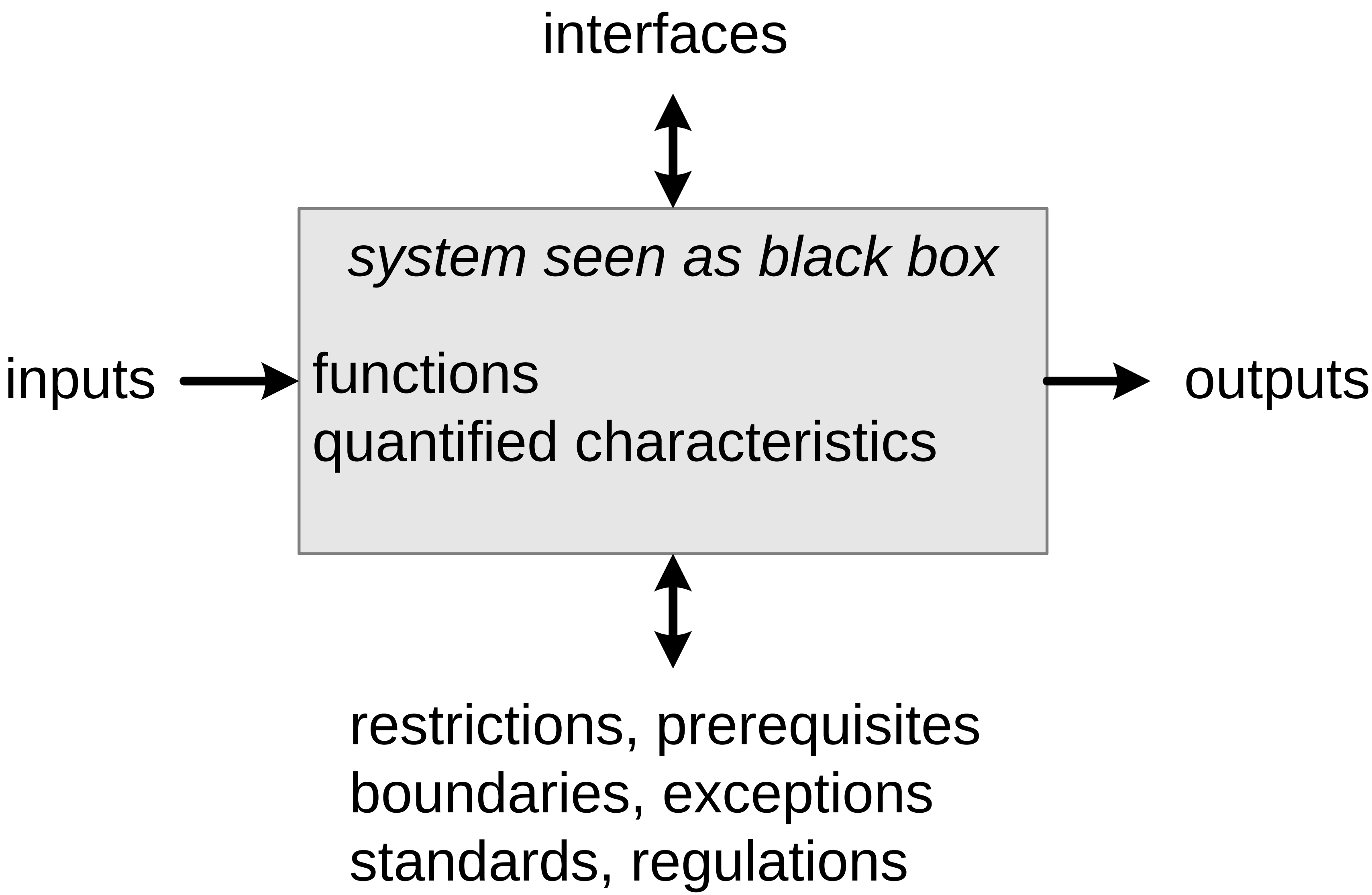


information model

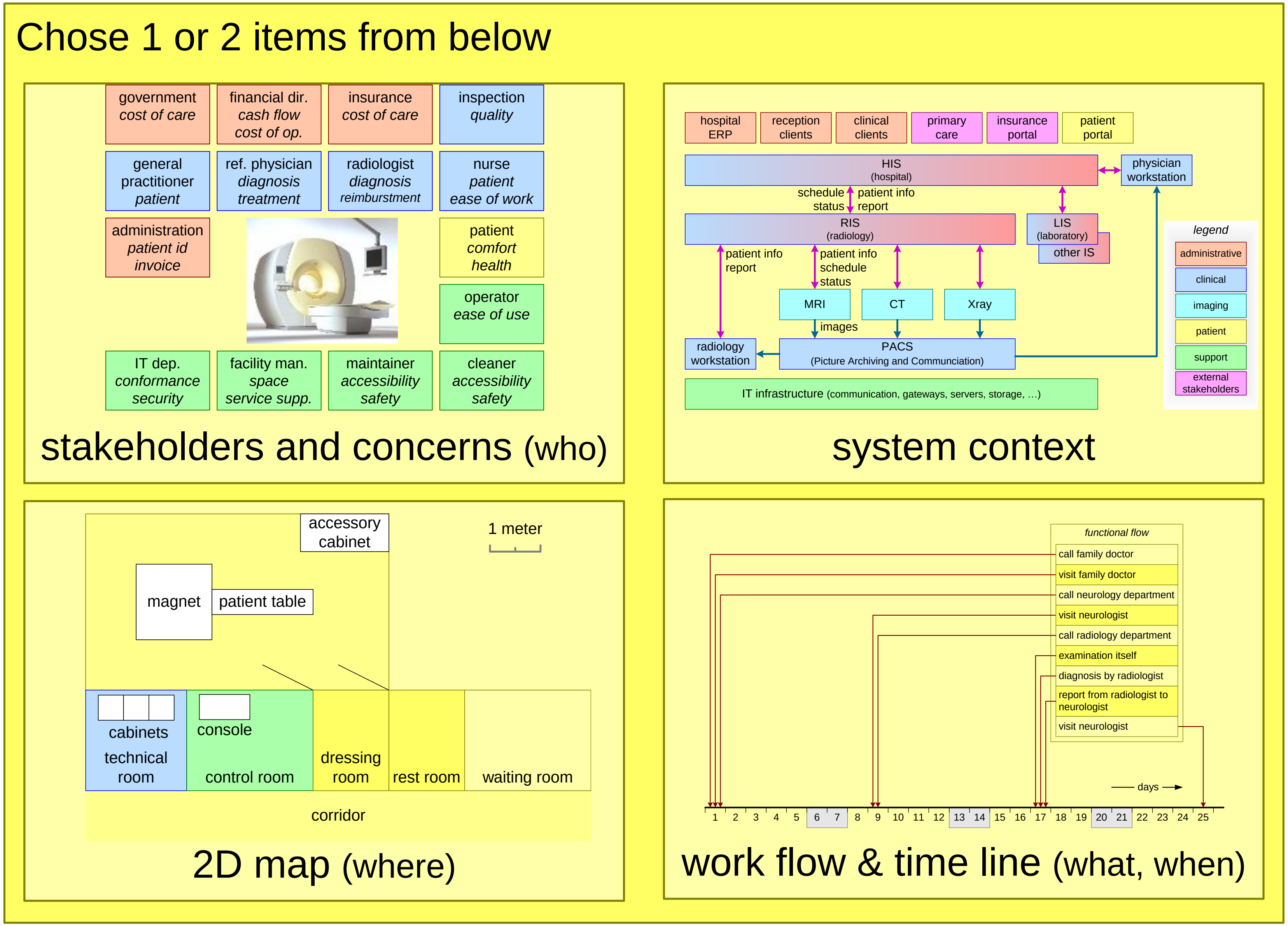


performance model

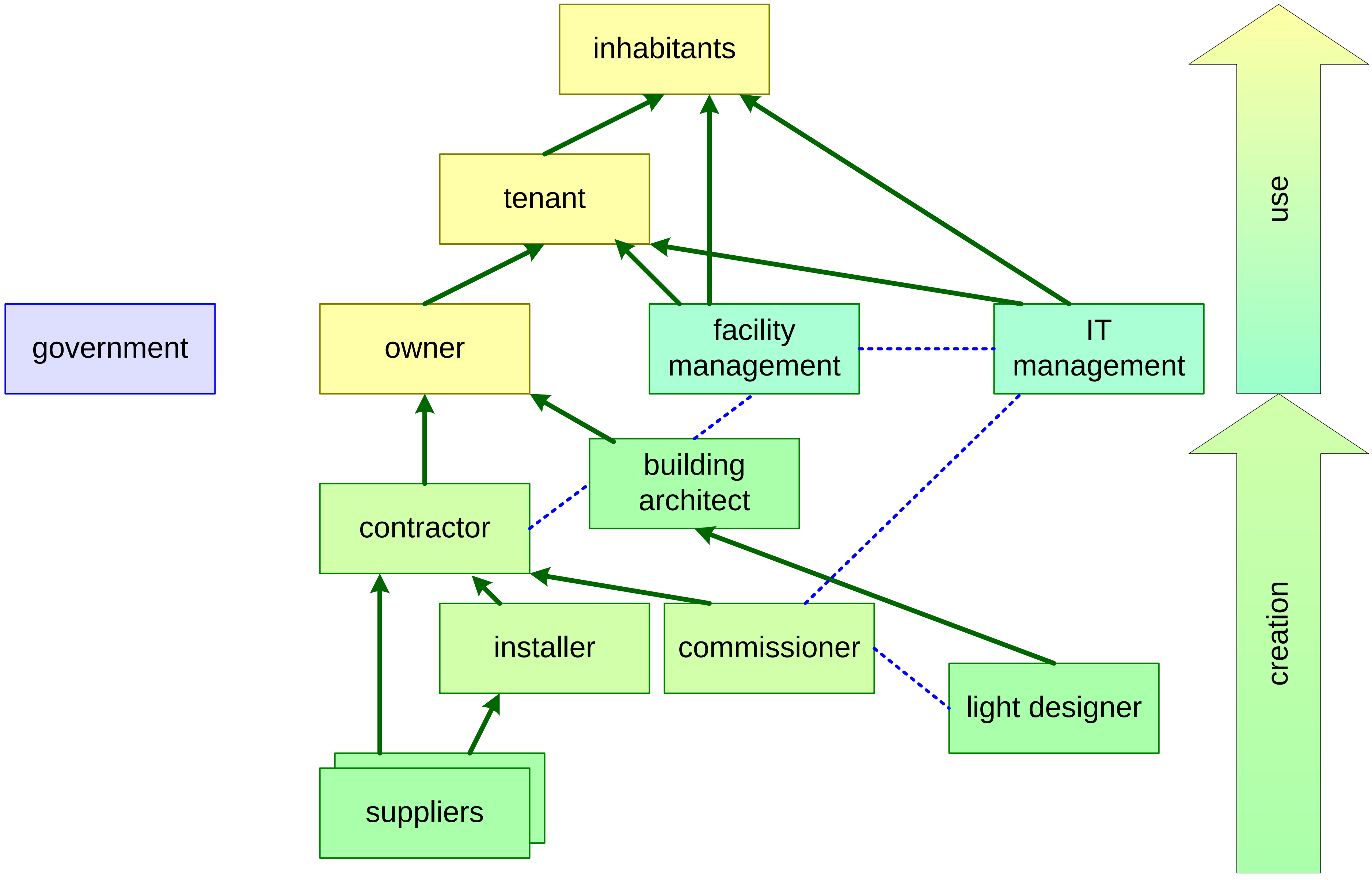
Step 3: Functional View; Top level Spec



Step 4: Application View



Step 5: Customer Objectives View; Value Network



Step 6: Qualities

Determine the 5 most relevant qualities from the checklist

- Make the chosen qualities as specific as possible
- Explain for each quality why it is relevant

Step 6: Qualities Checklist

usable
- usability
- attractiveness
- responsiveness
- image quality
- wearability
- storability
- transportability

dependable
- safety
- security
- reliability
- robustness
- integrity
- availability

effective
- throughput or productivity

interoperable
- connectivity
- 3rd party extendible

liable
- liability
- testability
- traceability
- standards compliance

efficient
- resource utilization
- cost of ownership

consistent
- reproducibility
- predictability

serviceable
- serviceability
- configurability
- installability

future proof
- evolvability
- portability
- upgradeability
- extendibility
- maintainability

logistics friendly
- manufacturability
- logistics flexibility
- lead time

ecological
- ecological footprint
- contamination
- noise
- disposability

down to earth attributes
- cost price
- power consumption
- consumption rate (water, air, chemicals, et cetera)
- size, weight
- accuracy

Presentation

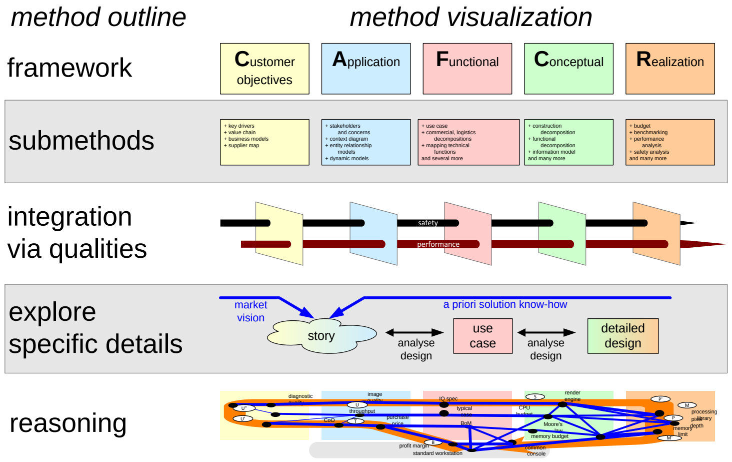
Present the results top-down

Use two to three flip charts of the six that have been created.

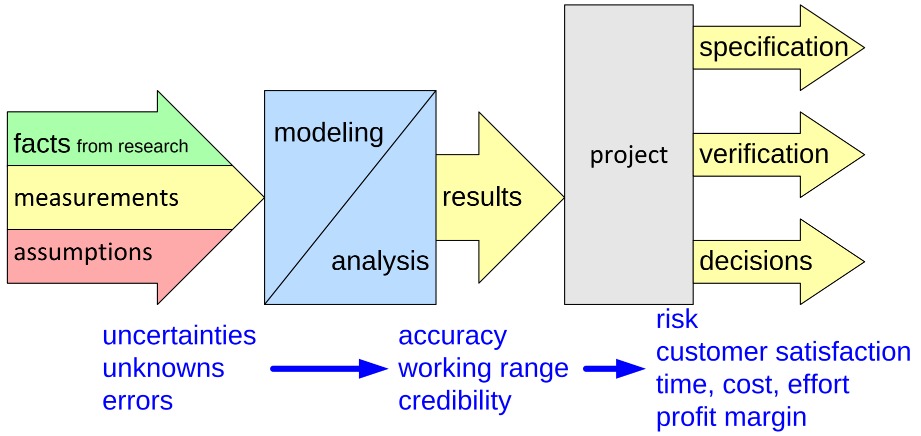
Explain in five minutes the needs of the customer, the system, and the major design choices.

Method Overview

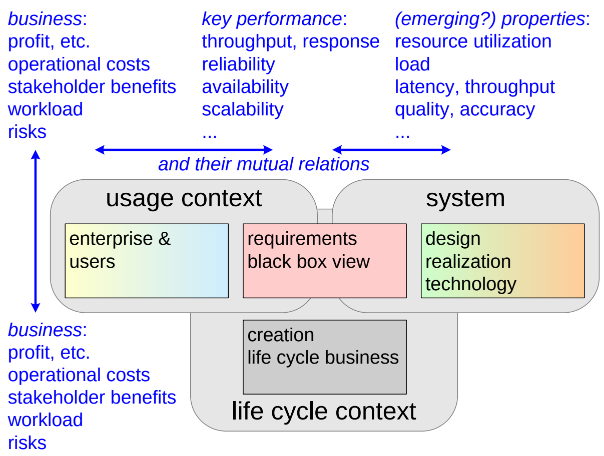
Architecting Method Overview



Modeling Method Overview



Modeling Scope



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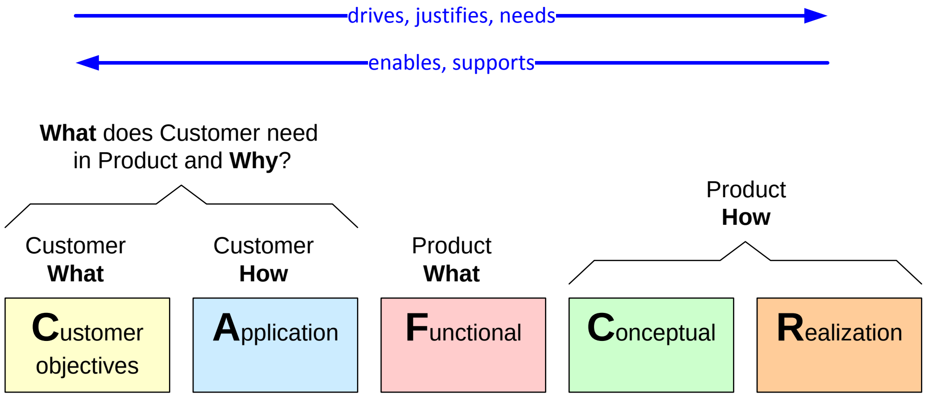
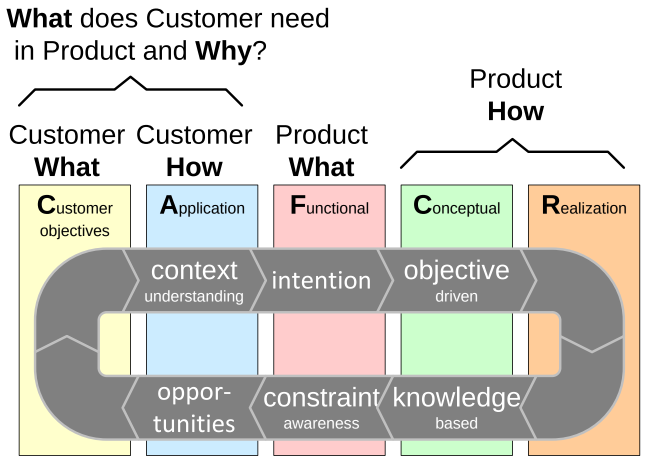
CAFCR

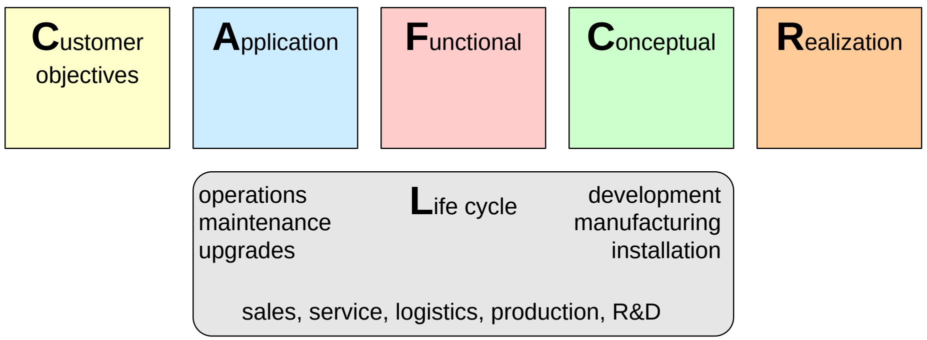
CAFCR views



Integrate and Iterate



Plus Life Cycle view



Sketch on Flips, Use Note stickers

Do	Do **not**	Because
• start sketching/drawing as soon as possible	• write long texts .	• sketches stimulate sharing and discussion
• use shared large sheets of paper (e.g. flip-over)	• immediately capture electronic	• sharing and discussion help to explore faster
• number the flip-overs and add a title		• remembering the order gets challenging
• annotate (add notes) during discussions	• have nice but volatile discussions	• information and insight is quickly lost
• use yellow note stickers and flip-over markers	• write with pen or pencil	• stickers are easily (re)moved
• be open for ideas and surprises	• Do not stick to the first solution	• you hopefully discover a lot; increased insight will change problem and solution

Module 32, Architectural Reasoning Customer Space Sampling

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

This module introduces Customer Space Sampling as part of the course Architectural Reasoning using Conceptual Modeling.

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Story How To

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

A story is an easily accessible story or narrative to make an application live. A good story is highly specific and articulated entirely in the problem domain: the native world of the users. An important function of a story is to enable specific (*quantified, relevant, explicit*) discussions.

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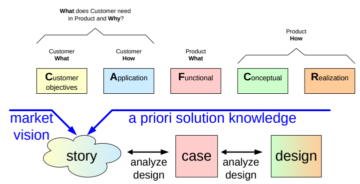
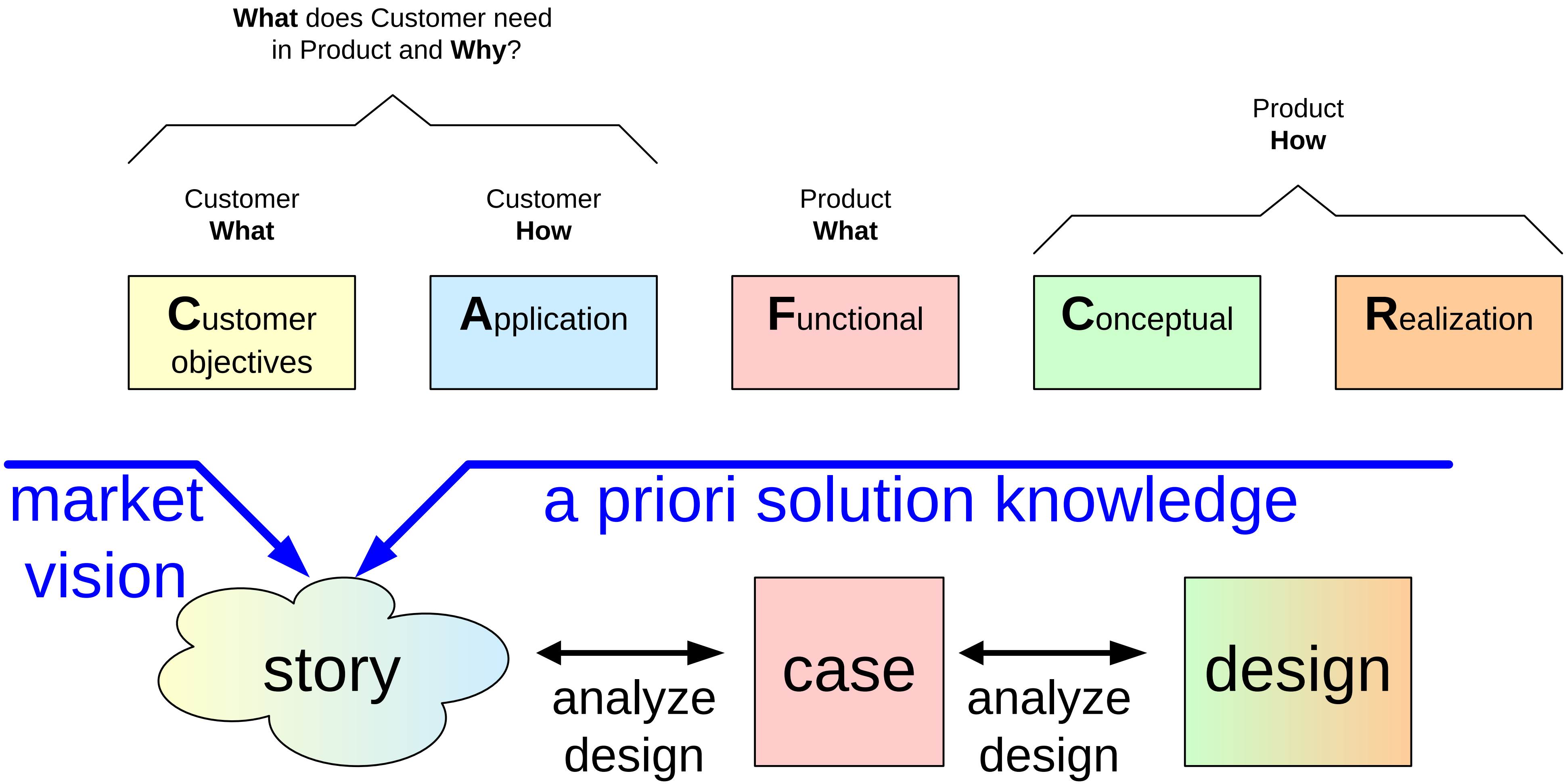
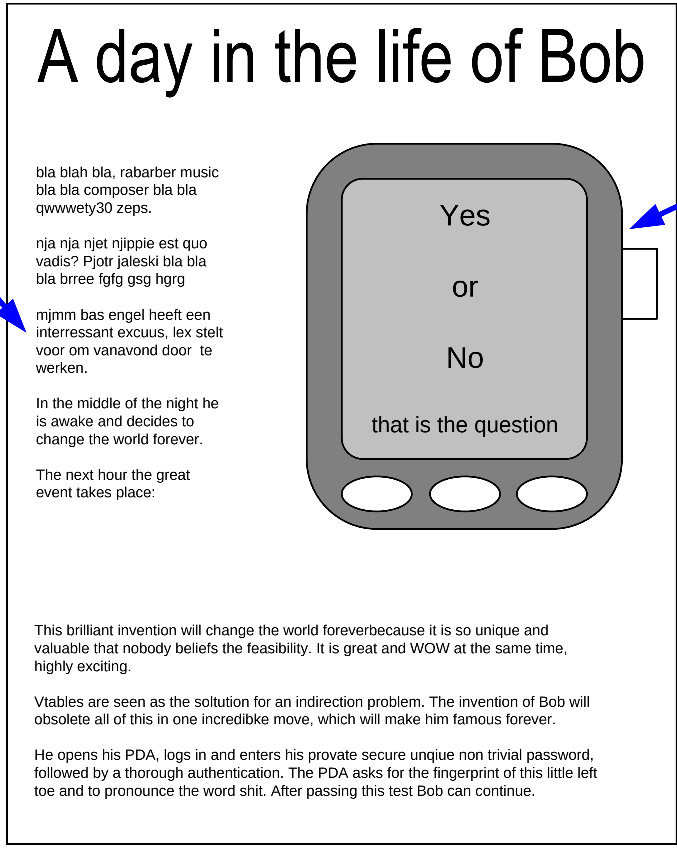


From story to design



Example story layout

ca. half a page of plain English text



draft or sketch of some essential appliance

Points of attention

- purpose — What do you need to know for specification and design?
- scope — “umbrella” or specific event?
- viewpoint, stakeholders — Define your stakeholder and viewpoint f.i. user, maintainer, installer
- visualization — Sketches or cartoon Helps to share and communicate ideas
- size (max 1 A4) — Can be read or told in few minutes
- recursive decomposition, refinement

Criteria for a good story

Customer objectives | **A**pplication
- accessible, understandable

"Do you see it in front of you?"

Customer objectives | **A**pplication
- valuable, appealing

attractive, important
"Are customers queuing up for this?"

Conceptual | **R**ealization
- critical, challenging

"What is difficult in the realization?"
"What do you learn w.r.t. the design?"

Application
- frequent, no exceptional niche

"Does it add significantly to the bottom line?"

Application | **F**unctional
- specific

names, ages, amounts, durations, titles, ...

Example of a story

Betty is a 70-year-old woman who lives in Eindhoven. Three years ago her husband passed away and since then she lives in a home for the elderly. Her 2 children, Angela and Robert, come and visit her every weekend, often with Betty's grandchildren Ashley and Christopher. As so many women of her age, Betty is reluctant to touch anything that has a technical appearance. She knows how to operate her television, but a VCR or even a DVD player is way to complex.

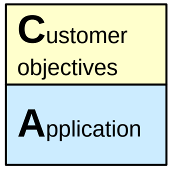
When Betty turned 60, she stopped working in a sewing studio. Her work in this noisy environment made her hard-of-hearing with a hearing-loss of 70dB around 2kHz. The rest of the frequency spectrum shows a loss of about 45dB. This is why she had problems understanding her grandchildren and why her children urged her to apply for hearing aids two years ago. Her technophobia (and her first hints or arthritis) inhibit her to change her hearing aids' batteries. Fortunately her children can do this every weekend.

This Wednesday Betty visits the weekly Bingo afternoon in the meetingplace of the old-folk's home. It's summer now and the tables are outside. With all those people there it's a lot of chatter and babble. Two years ago Betty would never go to the bingo: “I cannot hear a thing when everyone babbles and clatters with the coffee cups. How can I hear the winning numbers?!”. Now that she has her new digital hearing instruments, even in the bingo cacophony, she can understand everyone she looks at. Her social life has improved a lot and she even won the bingo a few times.

That same night, together with her friend Janet, she attends Mozart's opera The Magic Flute. Two years earlier this would have been one big low rumbly mess, but now she even hears the sparkling high piccolos. Her other friend Carol never joins their visits to the theaters. Carol also has hearing aids, however hers only “work well” in normal conversations. “When I hear music it's as if a butcher's knife cuts through my head. It's way too sharp!”. So Carol prefers to take her hearing aids out, missing most of the fun. Betty is so happy that her hearing instruments simply know where they are and adapt to their environment.

source: Roland Mathijssen
Embedded Systems Institute
Eindhoven

Value and Challenges in this story



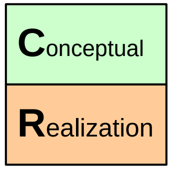
Value proposition in this story:

quality of life:

- active participation in different social settings

usability for nontechnical elderly people:

- "intelligent" system is simple to use
- loading of batteries



Challenges in this story:

Intelligent hearing instrument

Battery life — at least 1 week

No buttons or other fancy user interface on the hearing instrument, other than a robust On/Off method

The user does not want a technical device but a solution for a problem

Instrument can be adapted to the hearing loss of the user

Directional sensitivity (to prevent the so-called cocktail party effect)

Recognition of sound environments and automatic adaptation (adaptive filtering)

source: Roland Mathijssen, Embedded Systems Institute, Eindhoven

Exercise StoryTelling

Create a story

- as text + sketch or as cartoon

Use the criteria

- be highly specific!
- envision the future value proposition

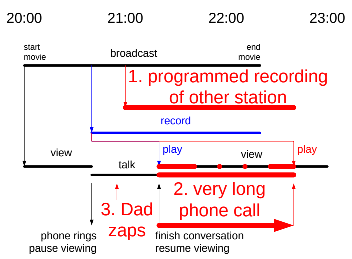
Enjoy!

Use Case How To

by *Gerrit Muller* University of South-Eastern Norway-NISE
e-mail: gaudisite@gmail.com
www.gaudisite.nl

Abstract

Use cases are frequently used in Software Engineering. Use cases support specification and facilitate design, analysis, verification and testing. Many designers, unfortunately, apply use cases in a rather limited way. This presentation provides recommendations for effective use cases.



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Why Use Cases?

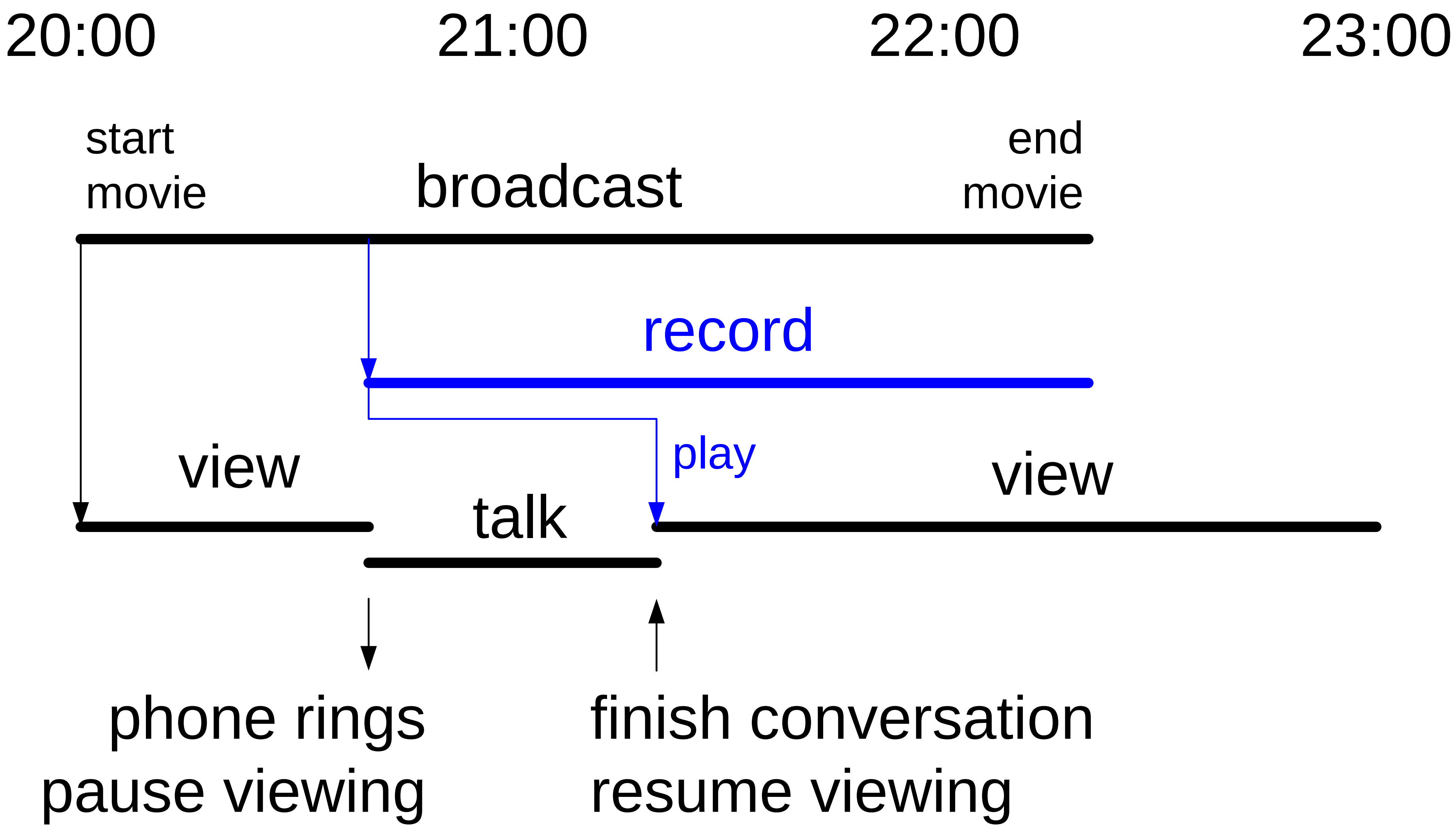
Supports or is part of specification

by providing specific data in user perspective

Facilitates analysis and design

Facilitates verification and testing

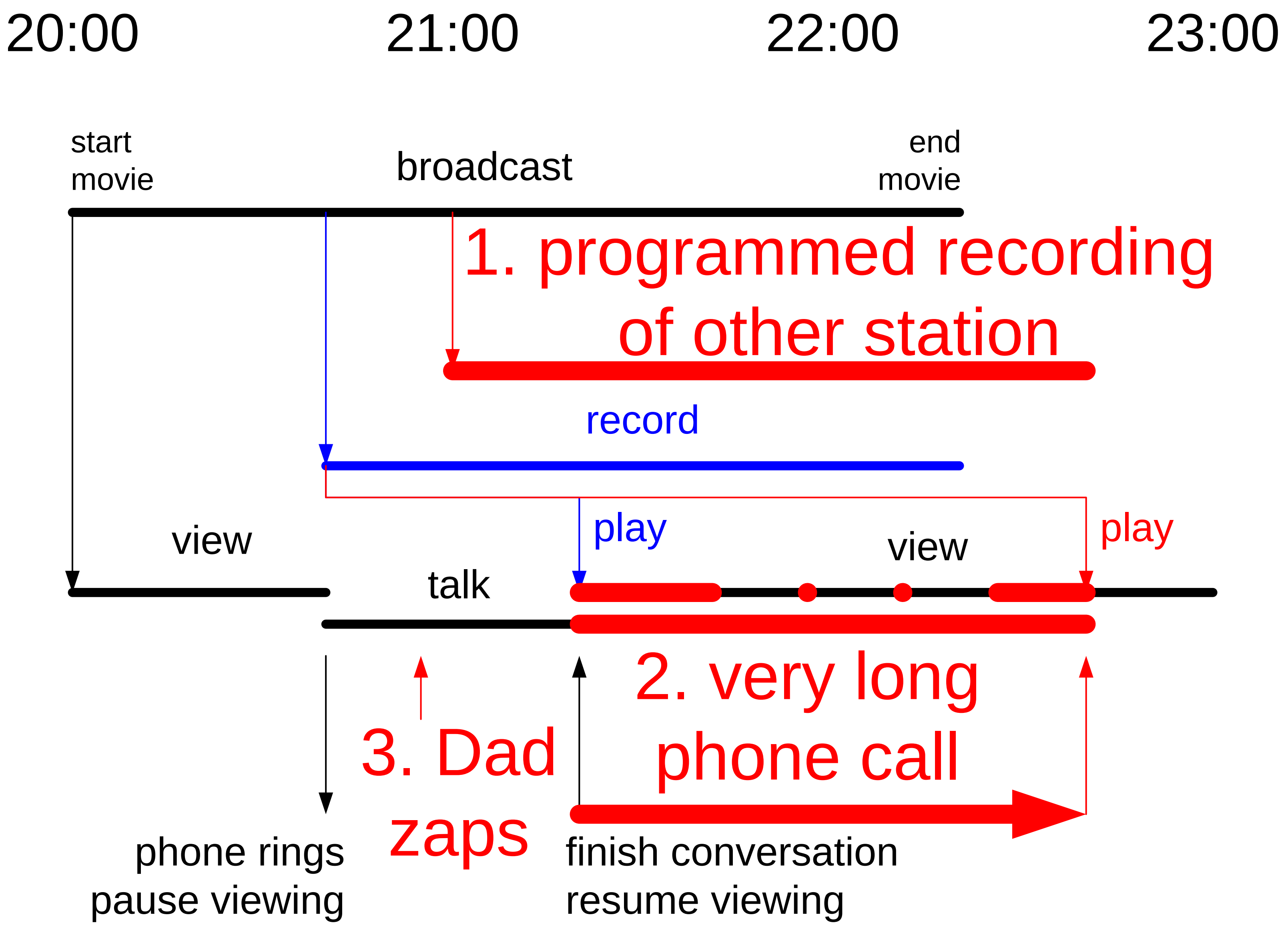
Example Time Shift recording



Construction limits intrude in User Experience

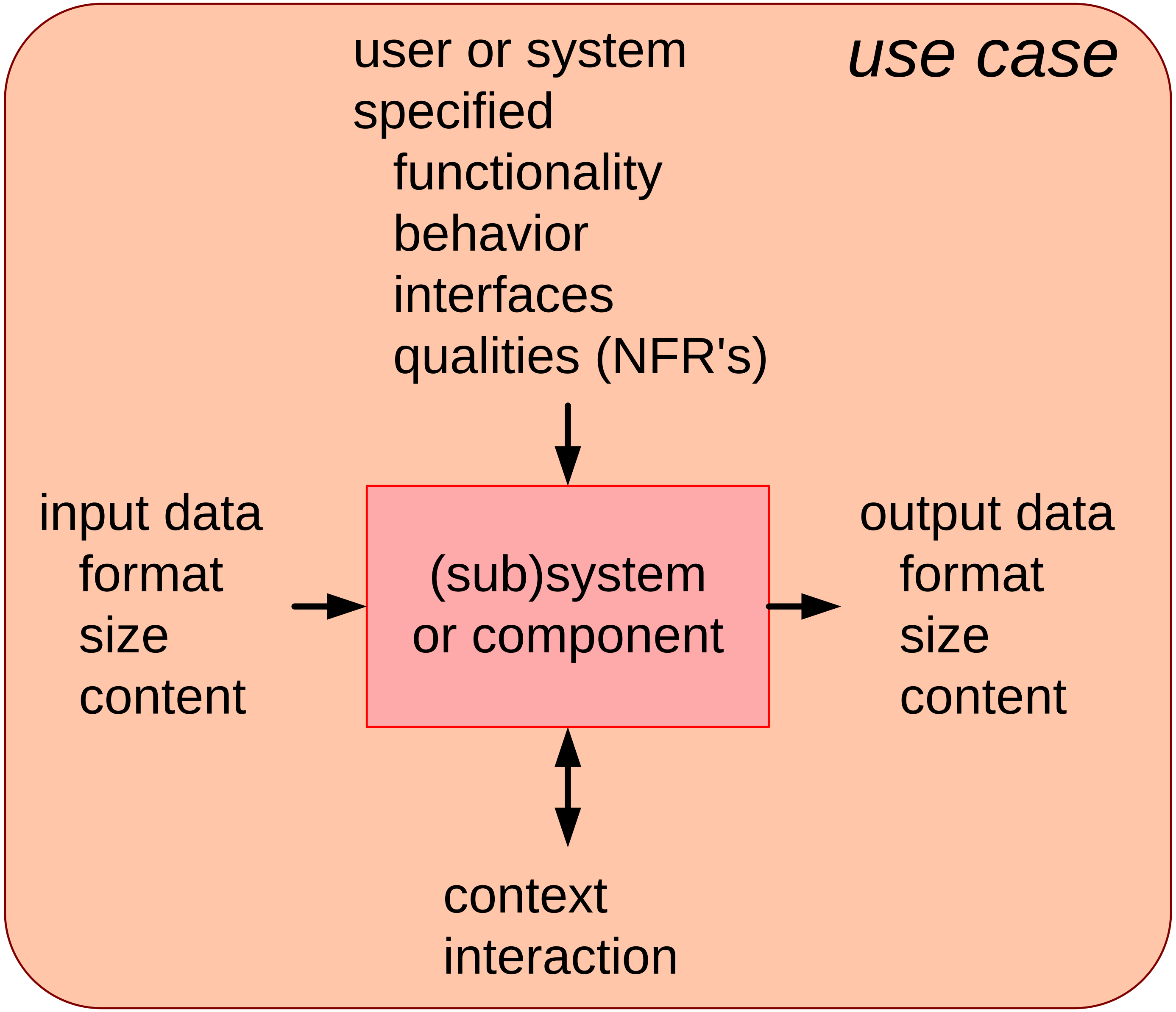
- number of tuners
- number of simultaneous streams (recording and playing)
- amount of available storage
- management strategy of storage space

What if?



20:00
21:00
22:00
23:00
start movie
broadcast
end movie
1. programmed recording of other station
record
view
talk
play
view
play
2. very long phone call
3. Dad zaps
phone rings pause viewing
finish conversation resume viewing

Content of a Use Case



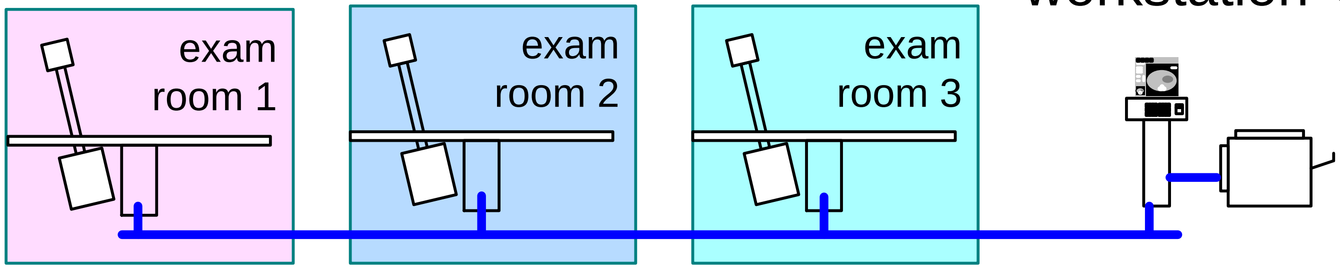
Example personal video recorder use case contents

typical use case(s)	worst case, exceptional, or change use case(s)
interaction flow (functional aspects) select movie via directory start movie be able to pause or stop be able to skip forward or backward set recording quality	**functional** multiple inputs at the same time extreme long movie directory behaviour in case of extreme many short movies
performance and other qualities (non-functional aspects) response times for start / stop response times for directory browsing end-of-movie behaviour relation recording quality and storage	**non-functional** response time with multiple inputs image quality with multiple inputs insufficient free space response time with many directory entries replay quality while HQ recording

Example of Quantification of Typical Use Case

3 examination rooms connected to

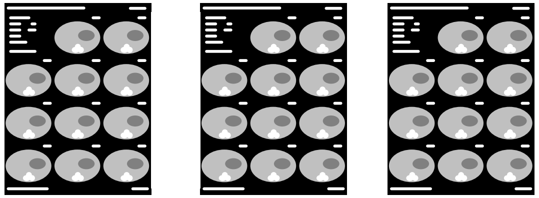
1 medical imaging workstation + printer



examination room: average 4 interleaved examinations / hour

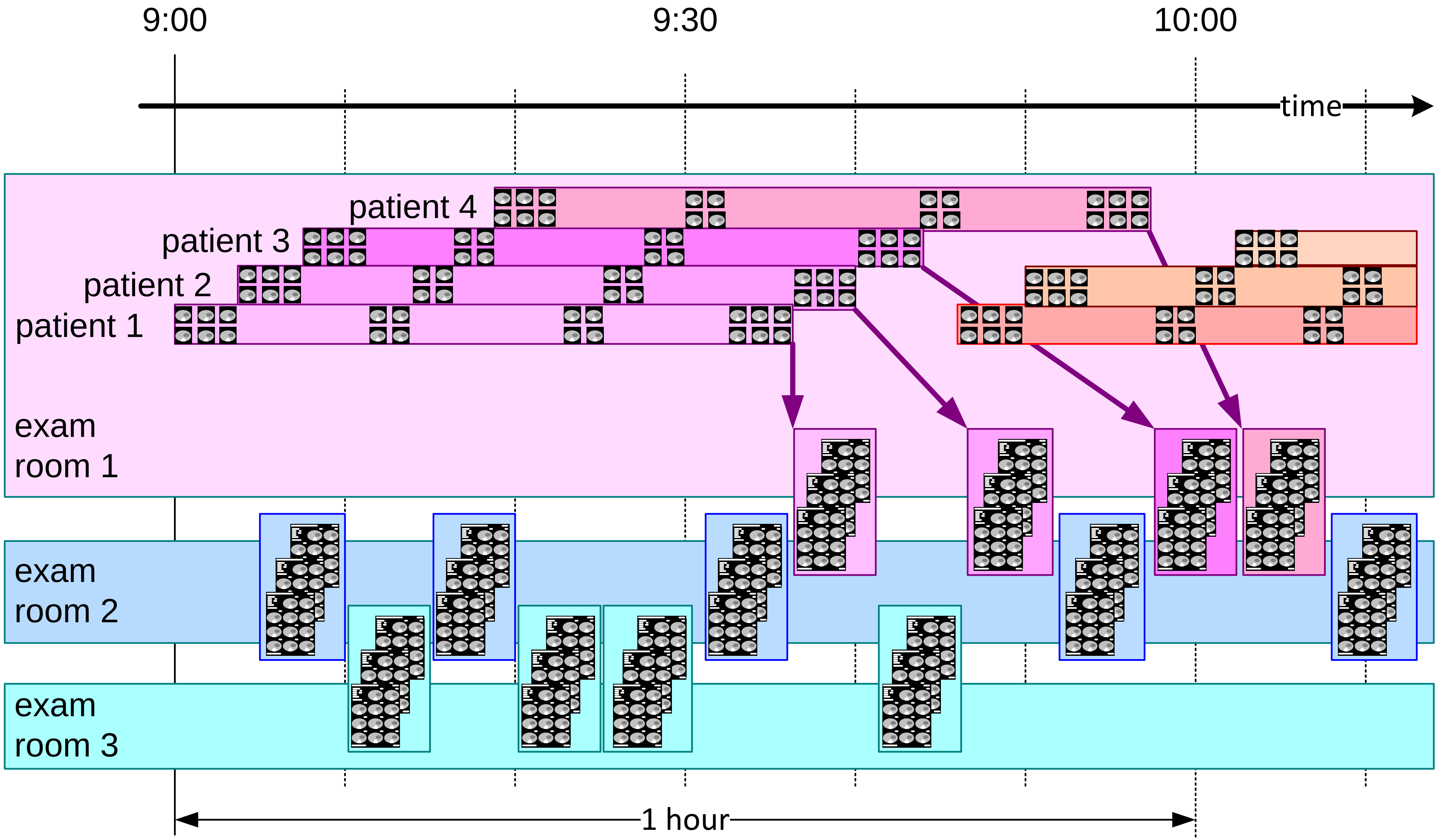
image production: 20 1024^2 8 bit images per examination

film production: 3 films of 4k*5k pixels each



high quality output
(bi-cubic interpolation)

Timing of this Use Case



Recommendations for working with use cases

+ combine related functions in one use case

- do not make a separate use case for every function

+ include non-functional requirements in the use cases

+ minimise the amount of required *worst case* and *exceptional use cases*

- excessive amounts of use cases propagate to excessive implementation efforts

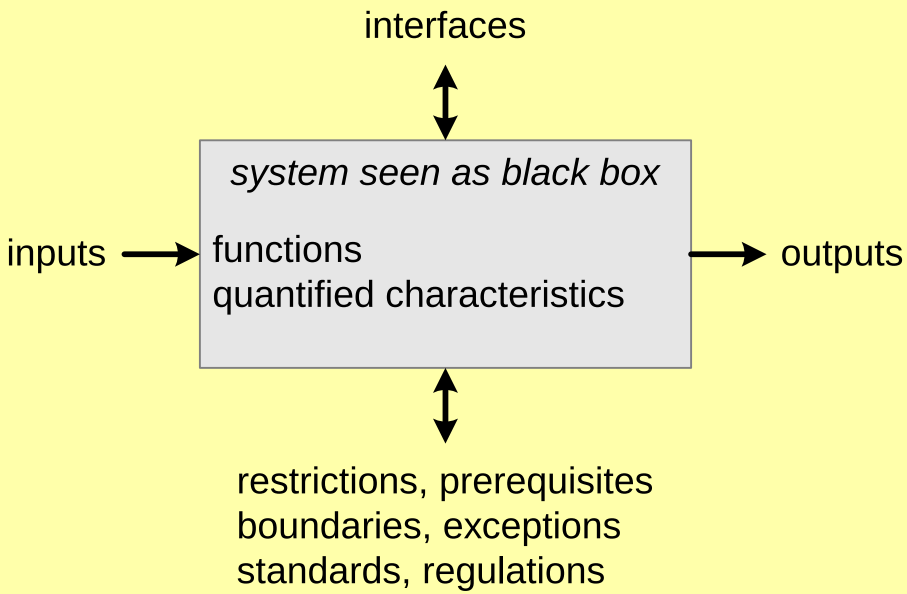
+ reduce the amount of these use cases in steps

- a few well chosen *worst case* use cases simplifies the design

Use Case Exercise

Make specification overview with ~10 **SMART** Key Performance Parameters (or functions or interfaces)

determine at least one use case

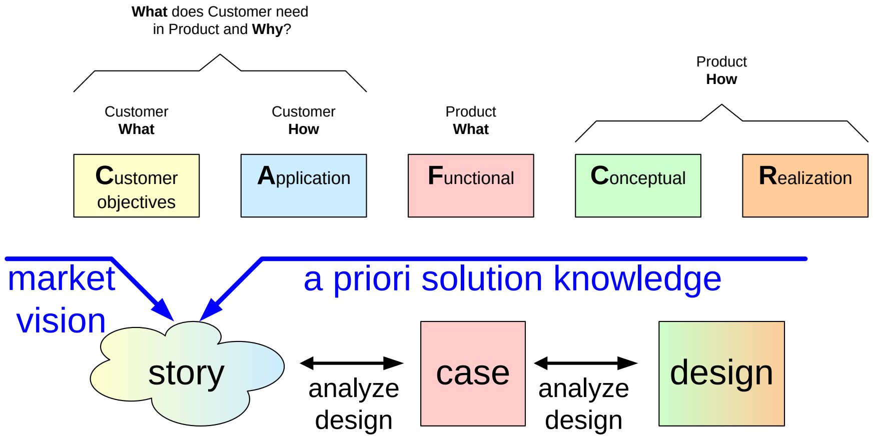


use case
typical use with relevant context data (quantified!)

- **S**pecific quantified
- **M**easurable verifiable
- **A**chievable (Attainable, Action oriented, Acceptable, Agreed-upon, Accountable)
- **R**ealistic (Relevant, Result-Oriented)
- **T**ime-bounded (Timely , Tangible, Traceable)

Story and Use Case Summary

Customer Language



Accesible and Specific to Learn

Customer objectives / Application
- accessible, understandable
  "Do you see it in front of you?"

Customer objectives / Application
- valuable, appealing
  attractive, important
  "Are customers queuing up for this?"

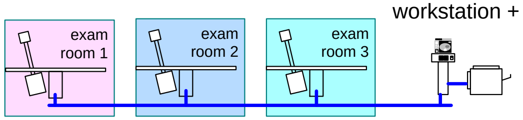
Conceptual / Realization
- critical, challenging
  "What is difficult in the realization?"
  "What do you learn w.r.t. the design?"

Application
- frequent, no exceptional niche
  "Does it add significantly to the bottom line?"

Application / Functional
- specific
  names, ages, amounts, durations, titles, ...

Use Cases include Quantification

3 examination rooms connected to 1 medical imaging workstation + printer



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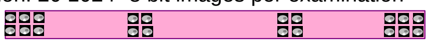
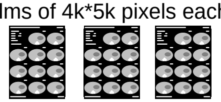


film production: 3 films of 4k*5k pixels each



high quality output
(bi-cubic interpolation)

Typical and Worst case

typical use case(s)	worst case, exceptional, or change use case(s)
interaction flow (functional aspects) select movie via directory start movie be able to pause or stop be able to skip forward or backward set recording quality	**functional** multiple inputs at the same time extreme long movie directory behaviour in case of extreme many short movies
performance and other qualities (non-functional aspects) response times for start / stop response times for directory browsing end-of-movie behaviour relation recording quality and storage	**non-functional** response time with multiple inputs image quality with multiple inputs insufficient free space response time with many directory entries replay quality while HQ recording

Module 33, Architectural Reasoning Design Fundamentals

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

This module discusses fundamental design methods and techniques, especially partitioning, interface, behavior, and quantified performance design.

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System Partitioning Fundamentals

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

e-mail: `gaudisite@gmail.com`

`www.gaudisite.nl`

Abstract

The fundamental concepts and approach system partitioning are explained. We look at physical decomposition and functional decomposition in relation to supply chain, lifecycle support, project management, and system specification and design.

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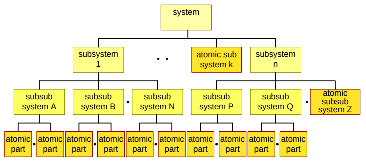
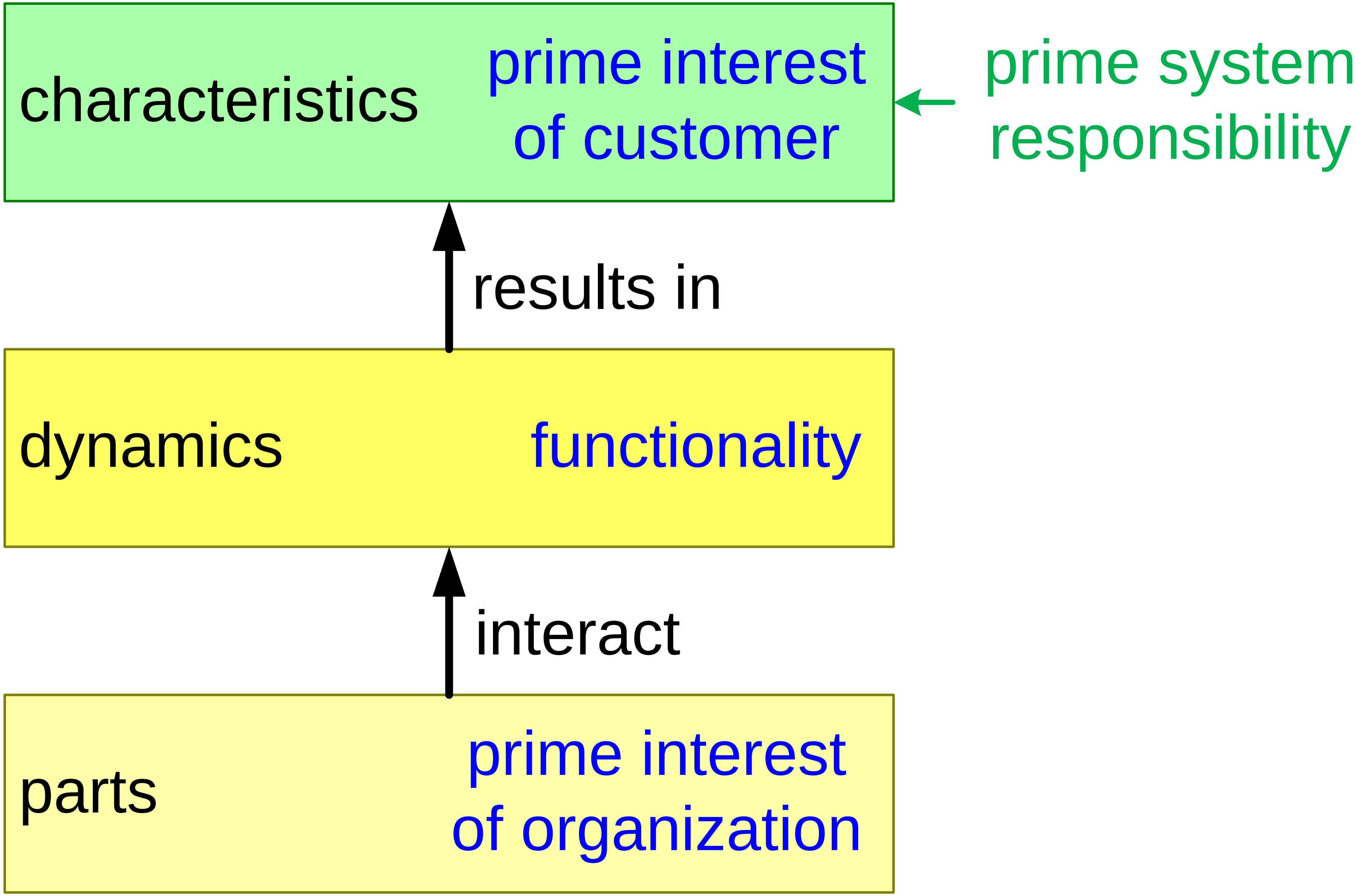
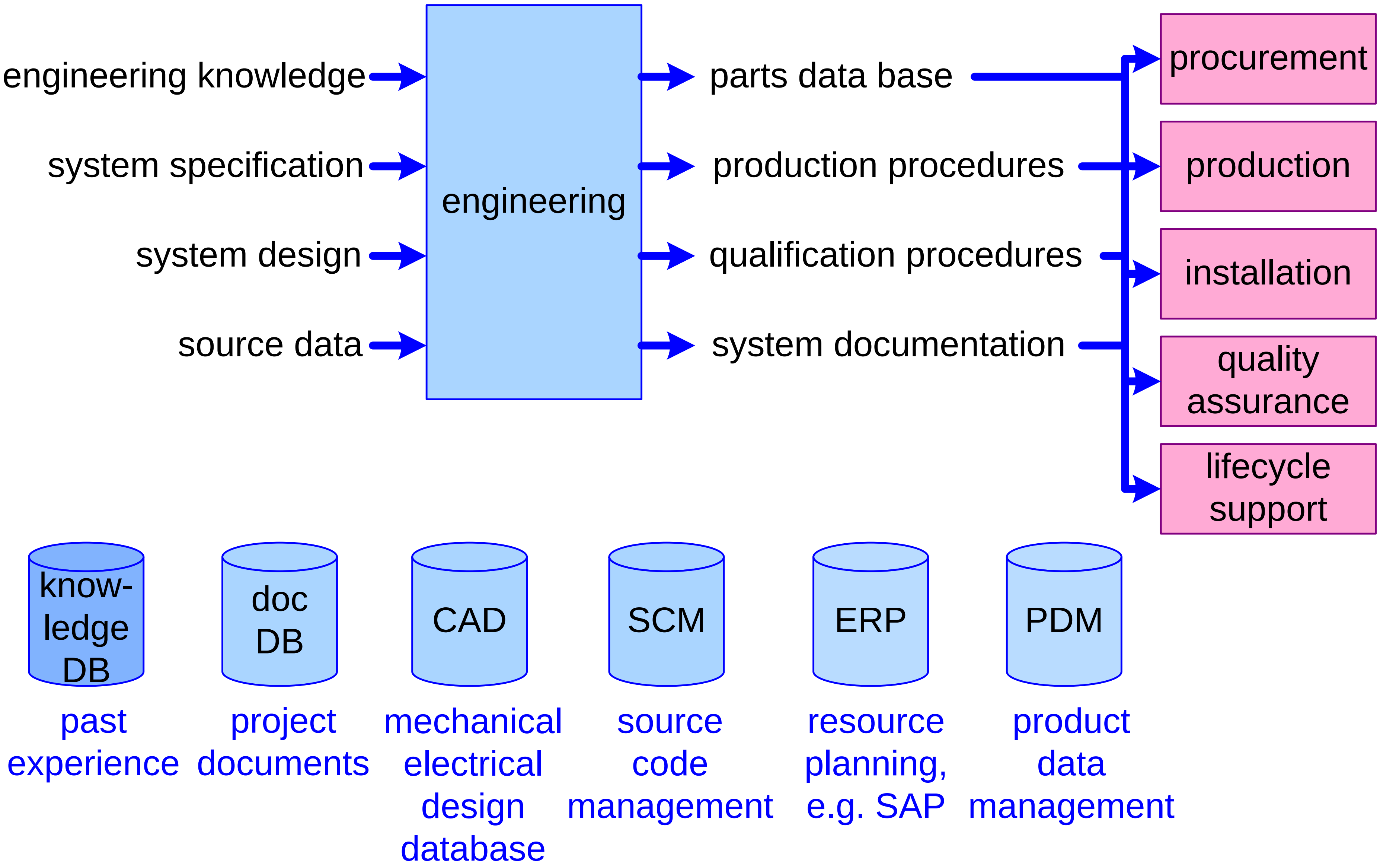


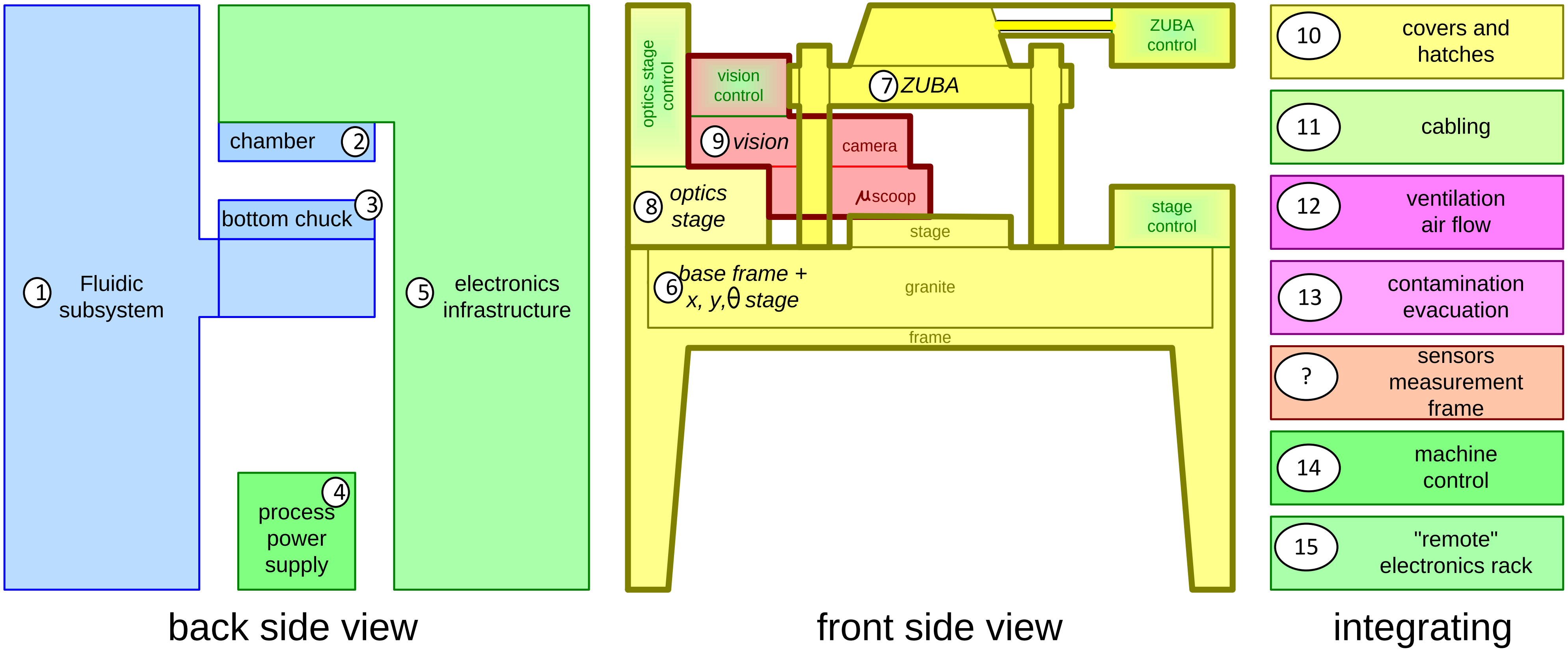
Parts, Dynamics, Characteristics



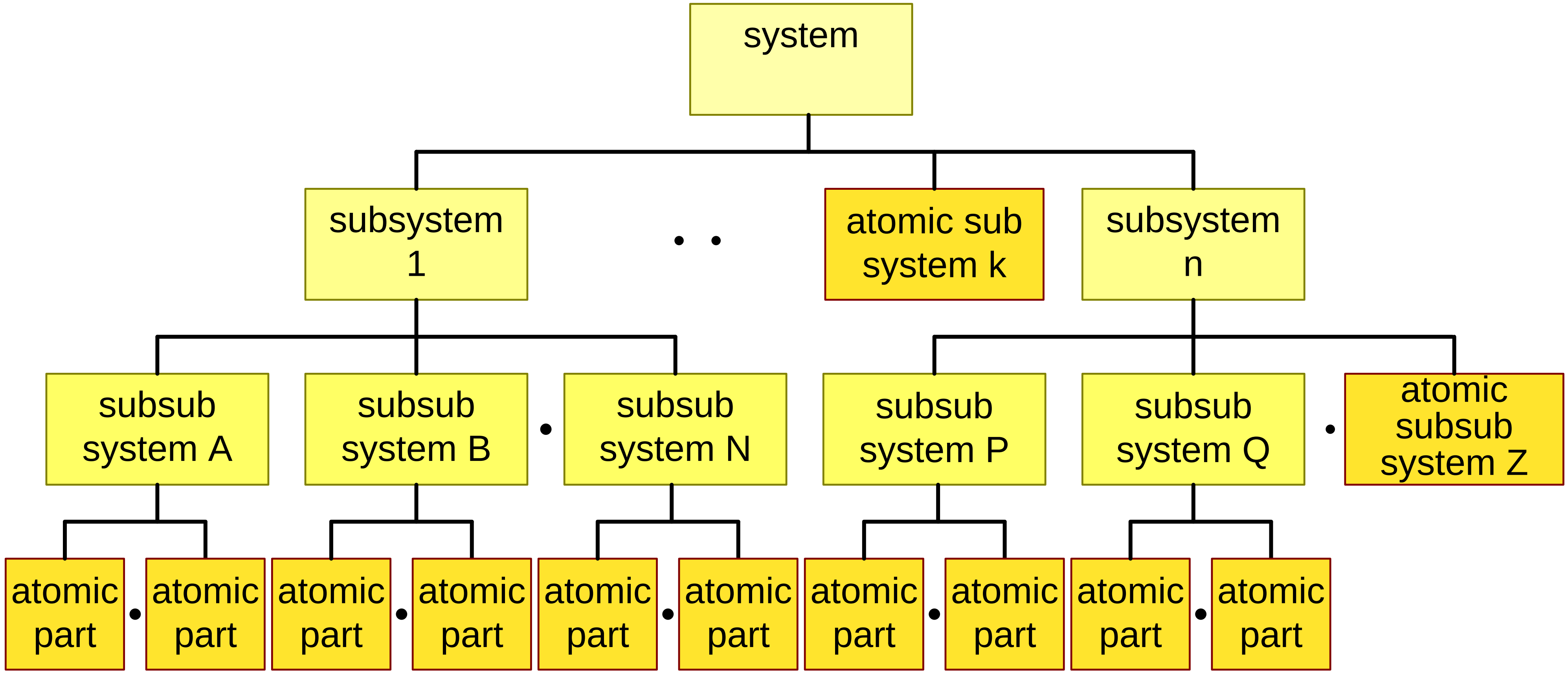
Engineering



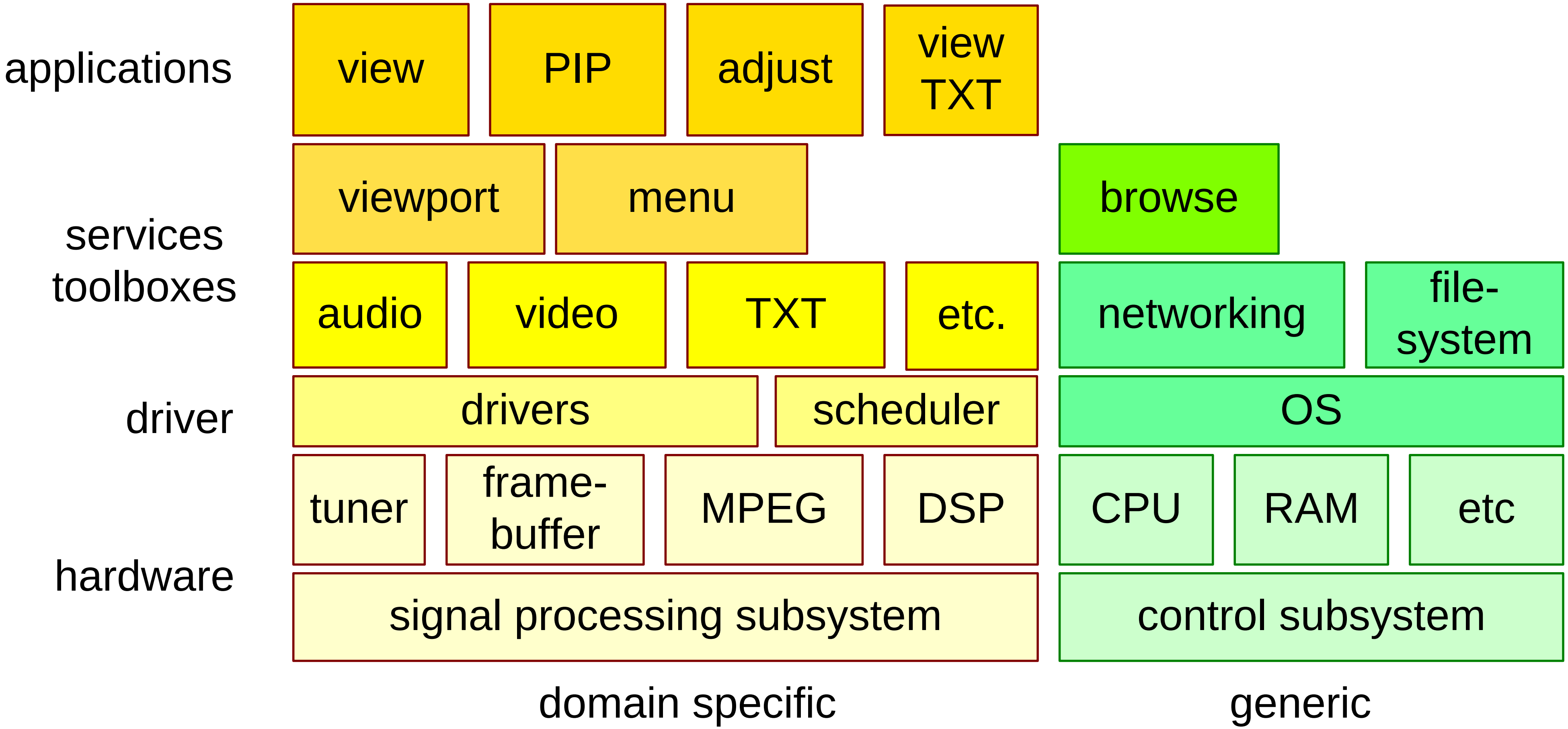
Example Physical Decomposition



Partitioning is Applied Recursively



Software plus Hardware Decomposition



Guidelines for Partitioning

the part is cohesive

functionality and technology belongs together

the coupling with other parts is minimal

minimize interfaces

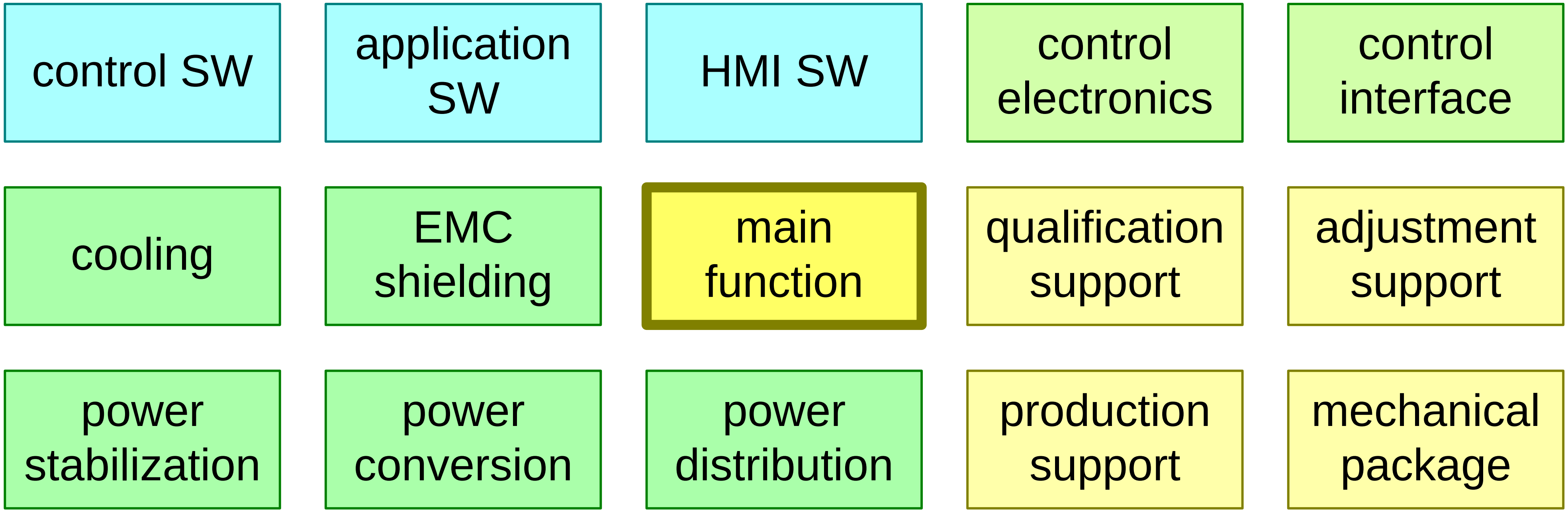
the part is selfsustained for production and qualification

can be in conflict with cost or space requirements

clear ownership of part

e.g. one department or supplier

How much self-sustained?

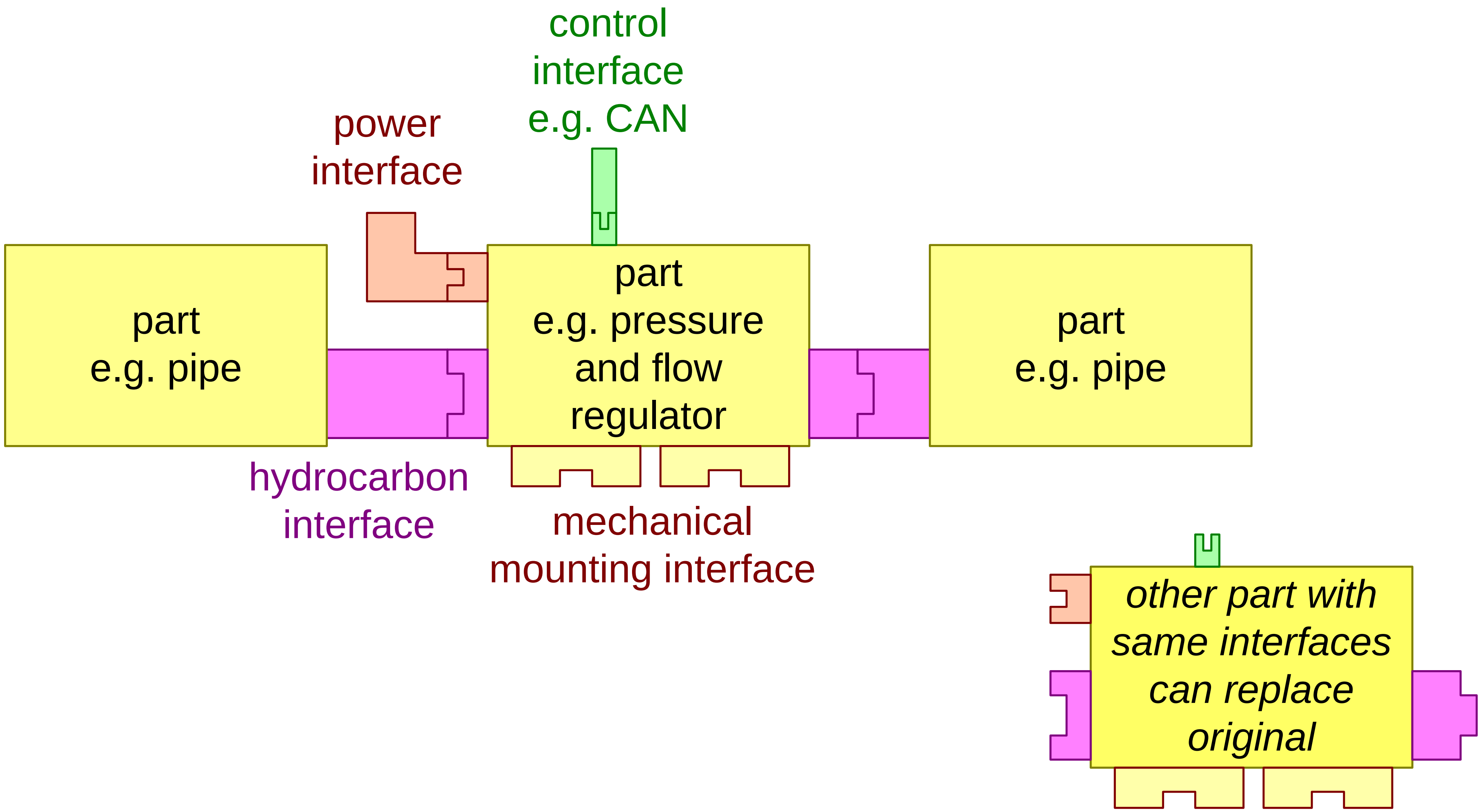


How self sustained should a part be?

trade-off:

cost/speed/space optimization ⟷ logistics/lifecycle/production flexibility clarity

Decoupling via Interfaces



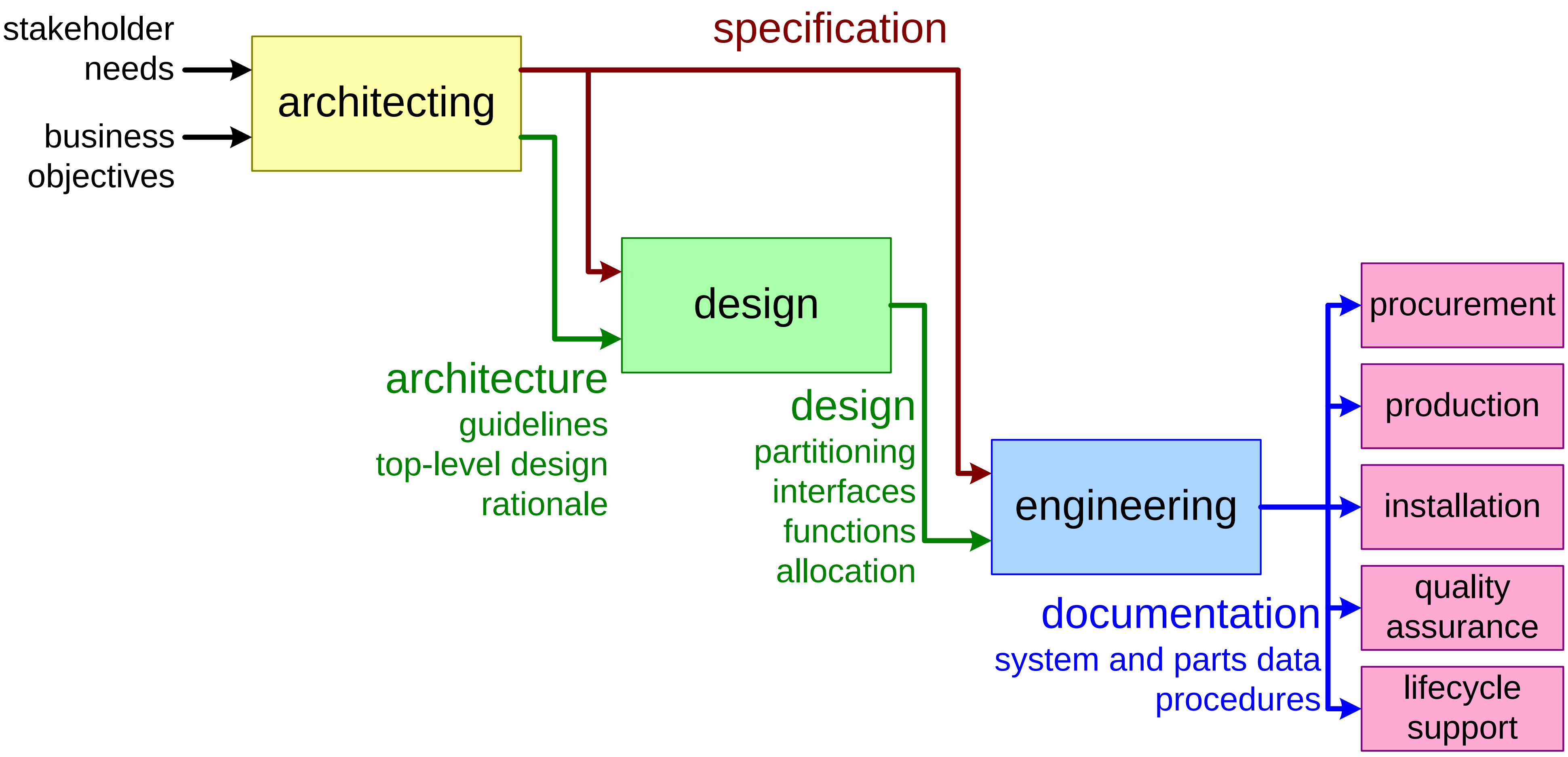
The Ideal Modularity

System is composed

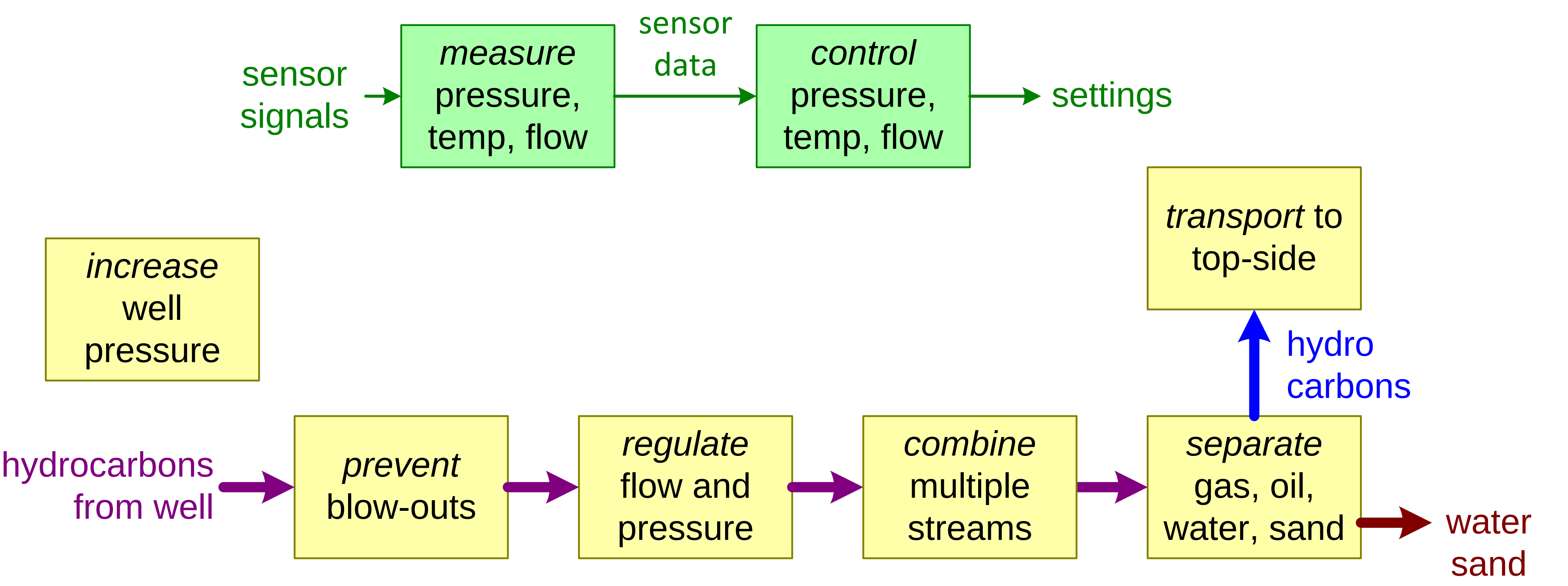
by using standard interfaces

limited catalogue of variants (e.g. cost performance points)

System Creation



Simplistic Functional SubSea Example



Functional Decomposition

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)
- information (e.g. measurements)
- control

At lower level one part ~= one function

- pump pumps, compressor compresses, controller controls

At higher level functions are complex interplay of physical parts

- e.g. regulating constant flow, pressure and temperature

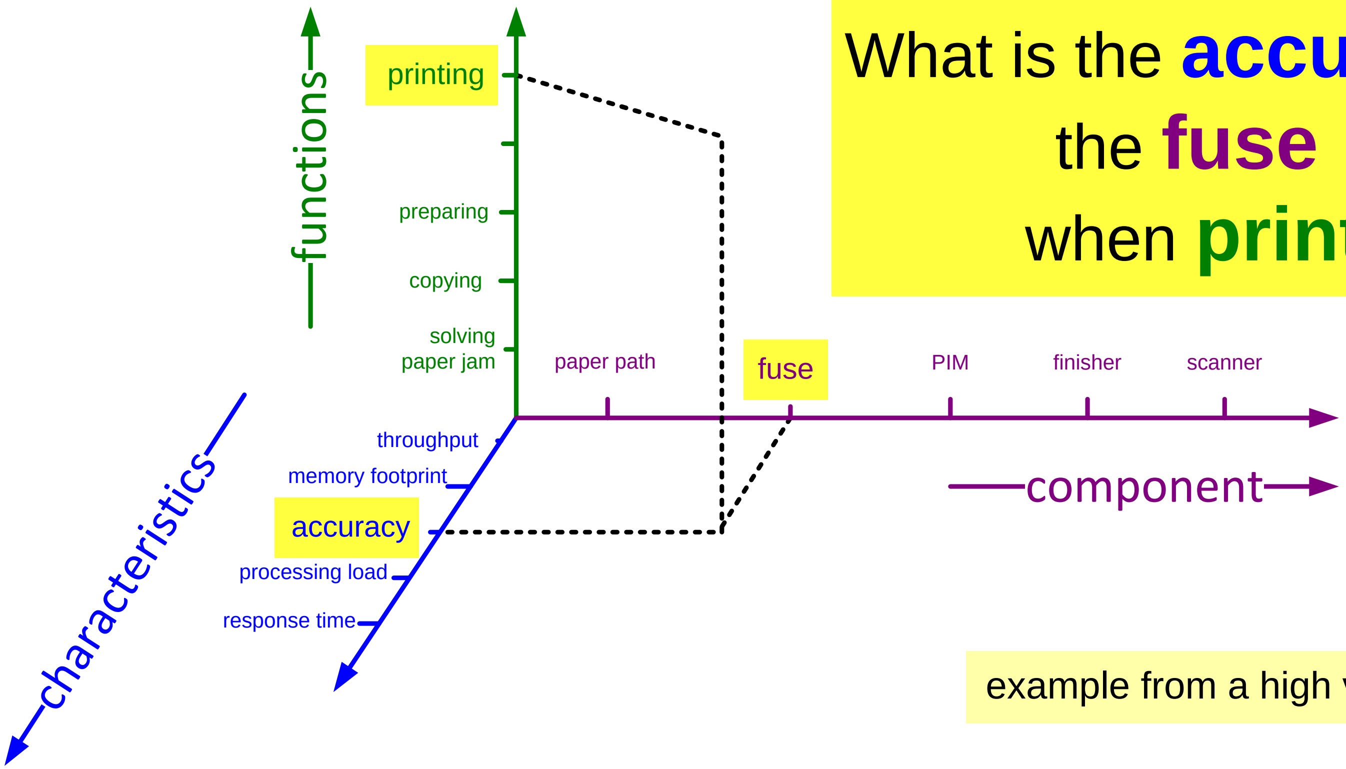
Quantification

Size	2.4m * 0.7m * 1.3m
Weight	1450 Kg
Cost	30000 NoK
Reliability	MTBF 4000 hr
Throughput	3000 l/hr
Response time	0.1 s
Accuracy	+/- 0.1%

many characteristics
of a system, function or part
can be quantified

Note that quantities
*have a **unit***

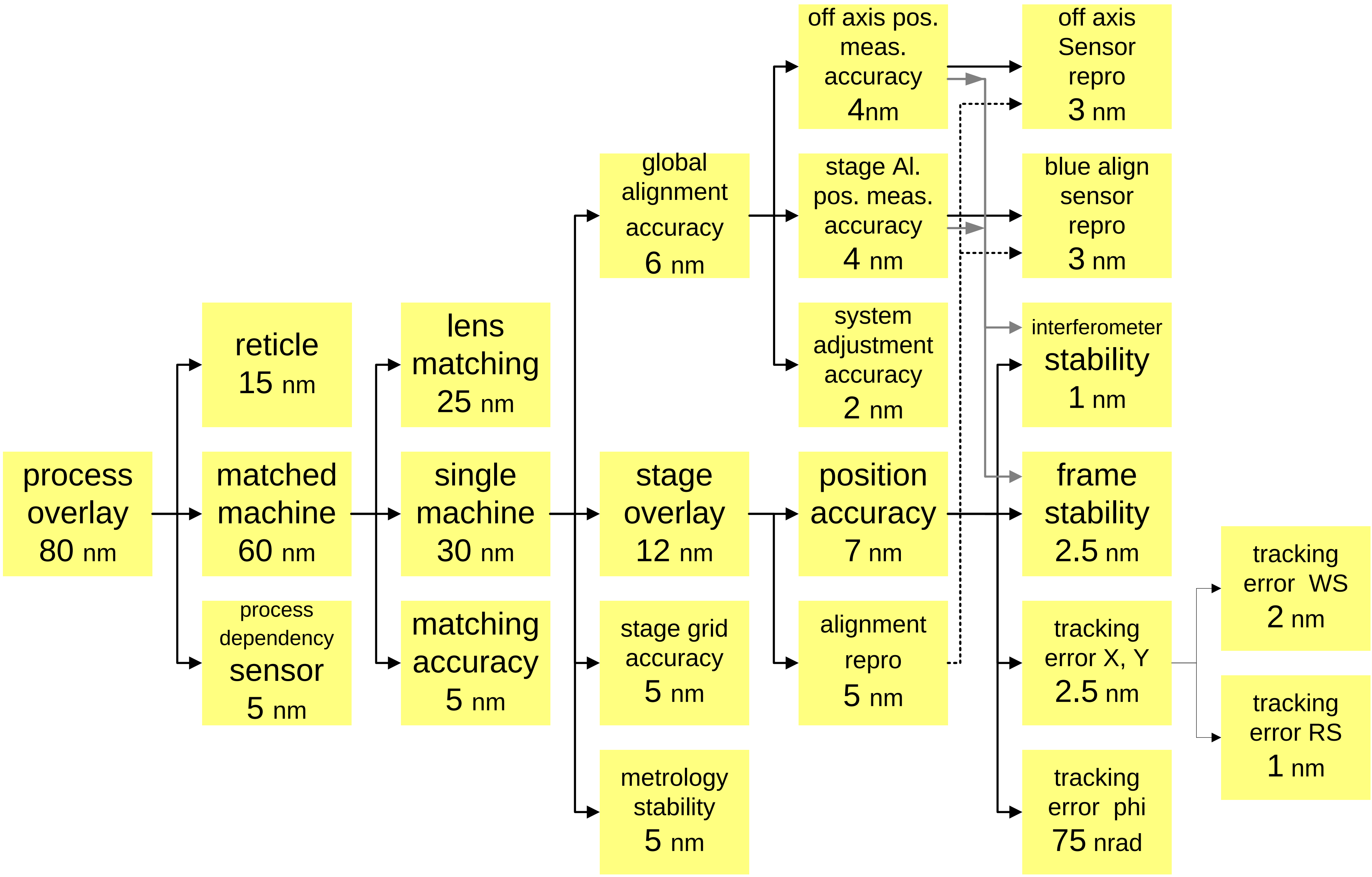
How about the **<characteristic>**
of the **<component>**
when performing **<function>**?



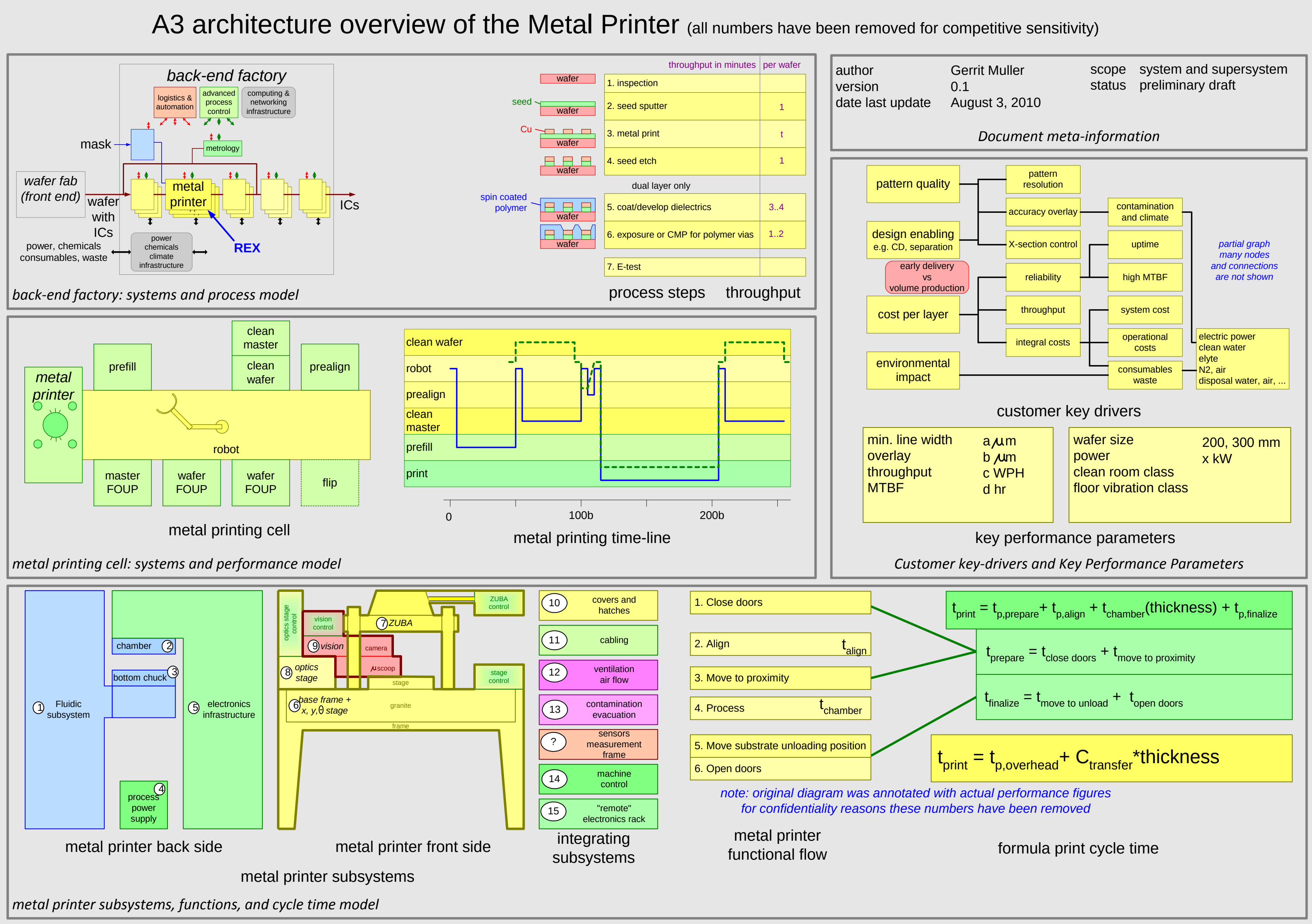
What is the **accuracy** of the **fuse** when **printing**

example from a high volume printer

Example Technical Budget



Example of A3 overview



Visualizing Dynamic Behavior

by *Gerrit Muller*   TNO-ESI, University of South-Eastern Norway]
e-mail: `gaudisite@gmail.com`
`www.gaudisite.nl`

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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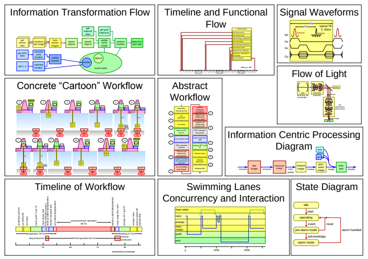
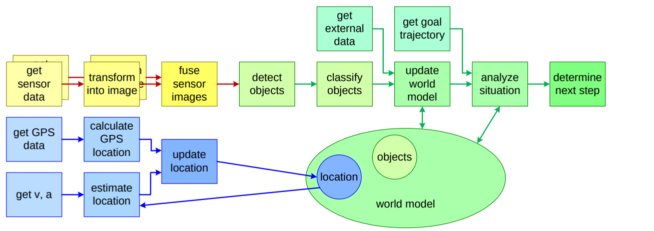
July 3, 2023
status: preliminary draft
version: 0

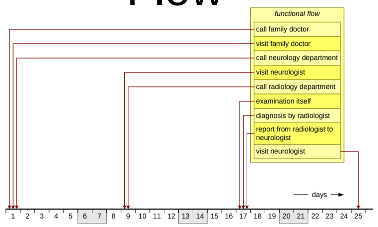


Overview of Visualizations of Dynamic Behavior

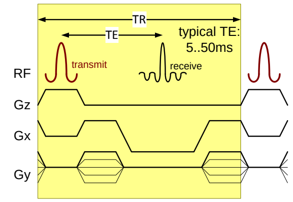
Information Transformation Flow



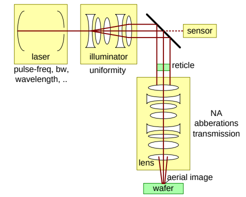
Timeline and Functional Flow



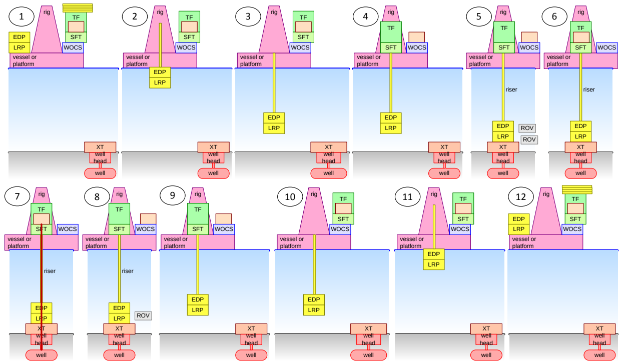
Signal Waveforms



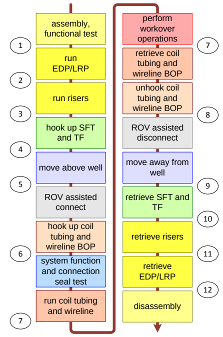
Flow of Light



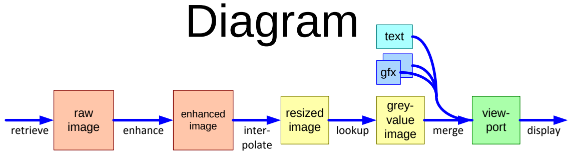
Concrete "Cartoon" Workflow



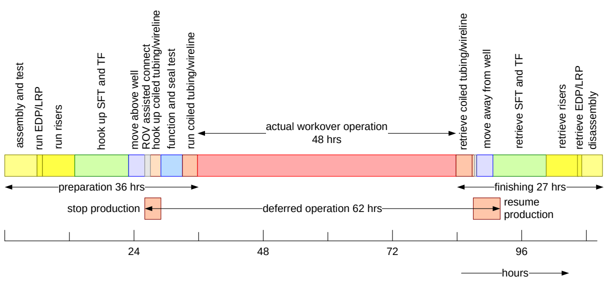
Abstract Workflow



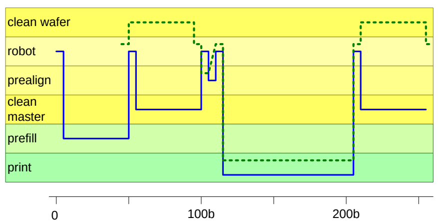
Information Centric Processing Diagram



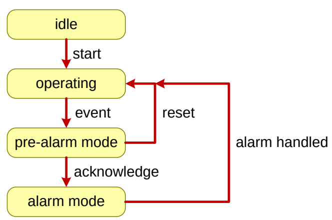
Timeline of Workflow



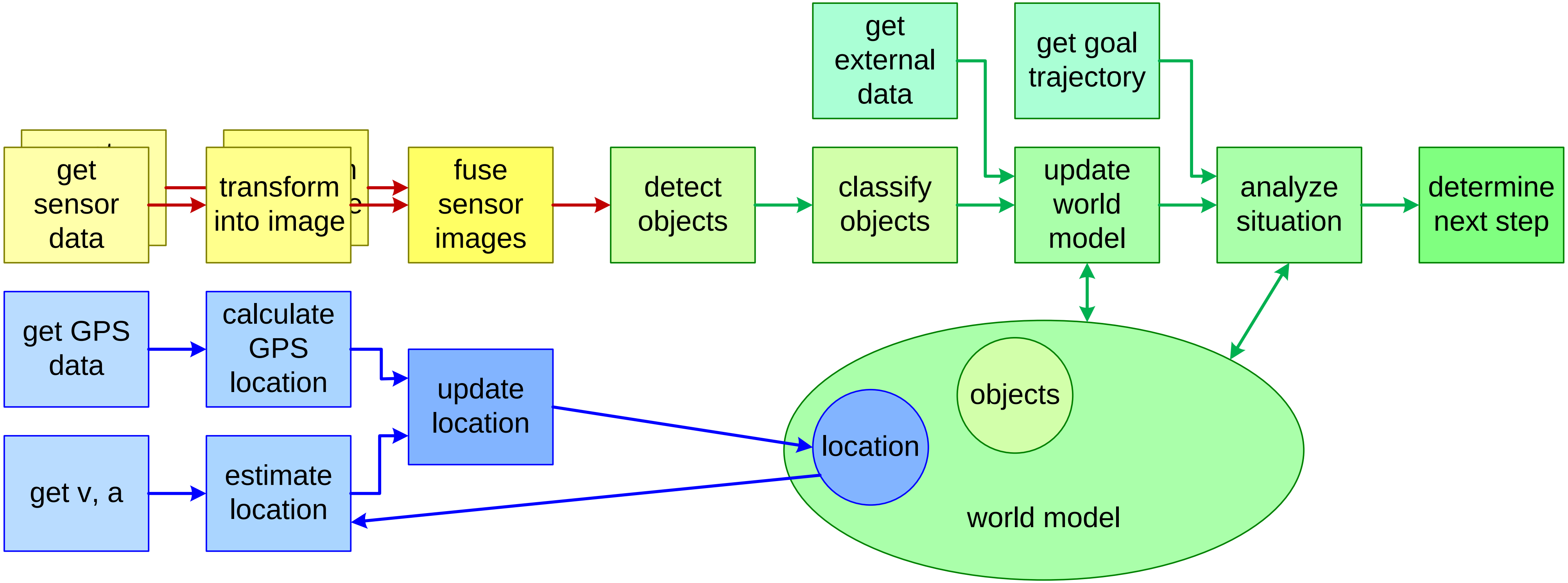
Swimming Lanes Concurrency and Interaction



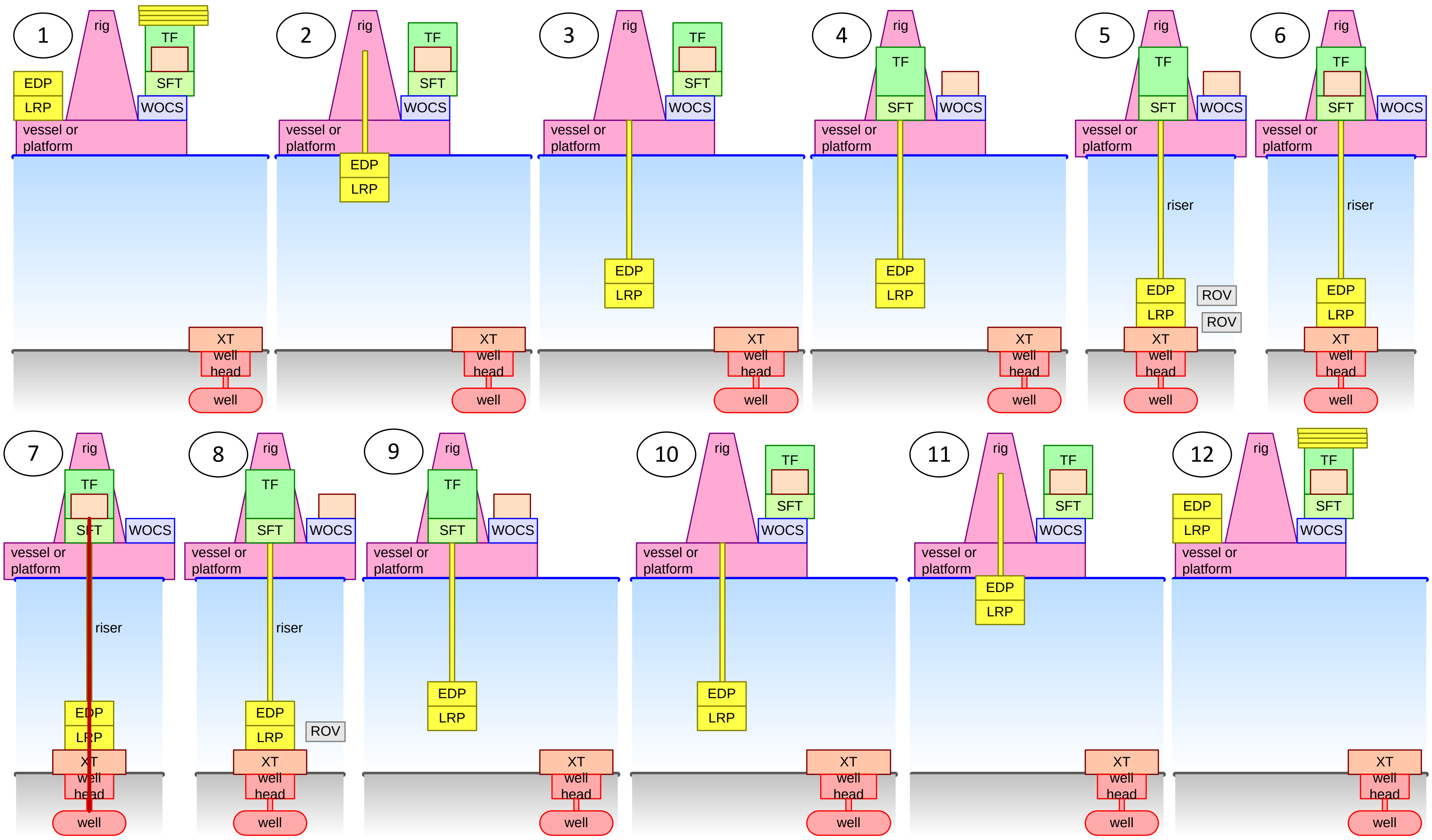
State Diagram



Example Functional Model of Information Flow

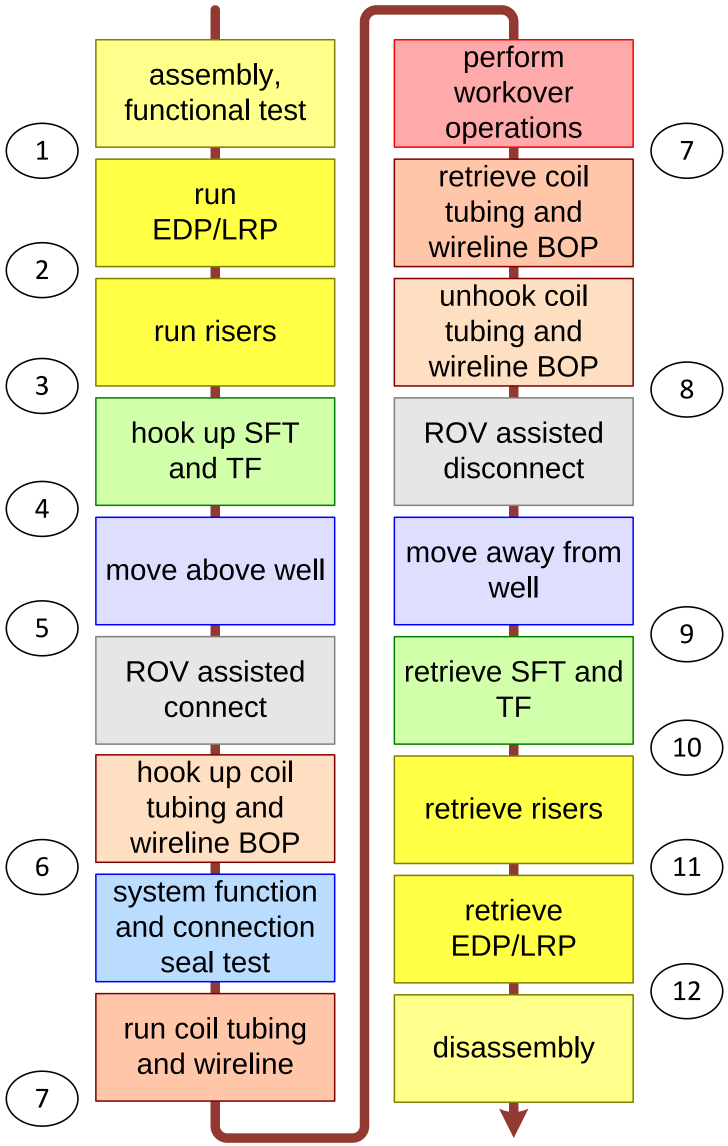


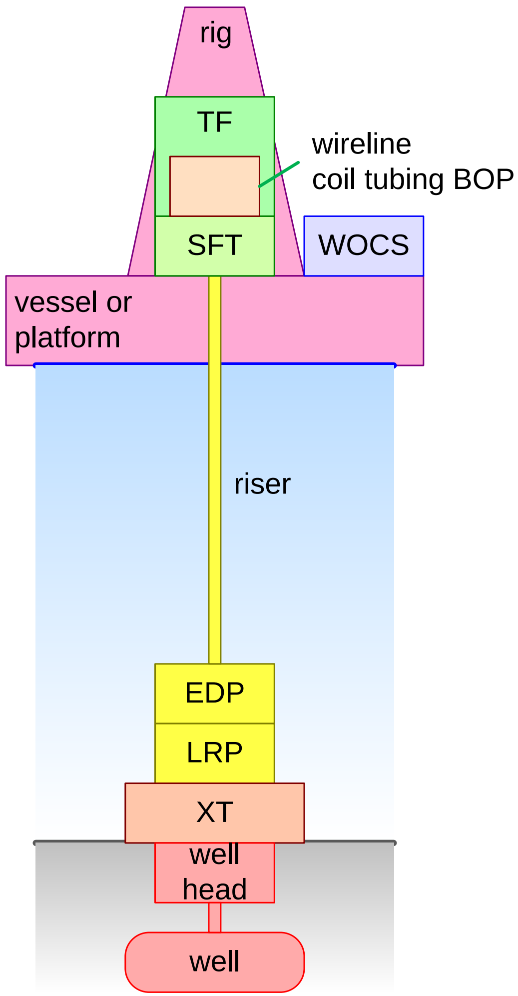
"Cartoon" Workflow



version: 0
July 3, 2023
SSMEtypicalWorkoverOperationCartoon

Workflow as Functional Model





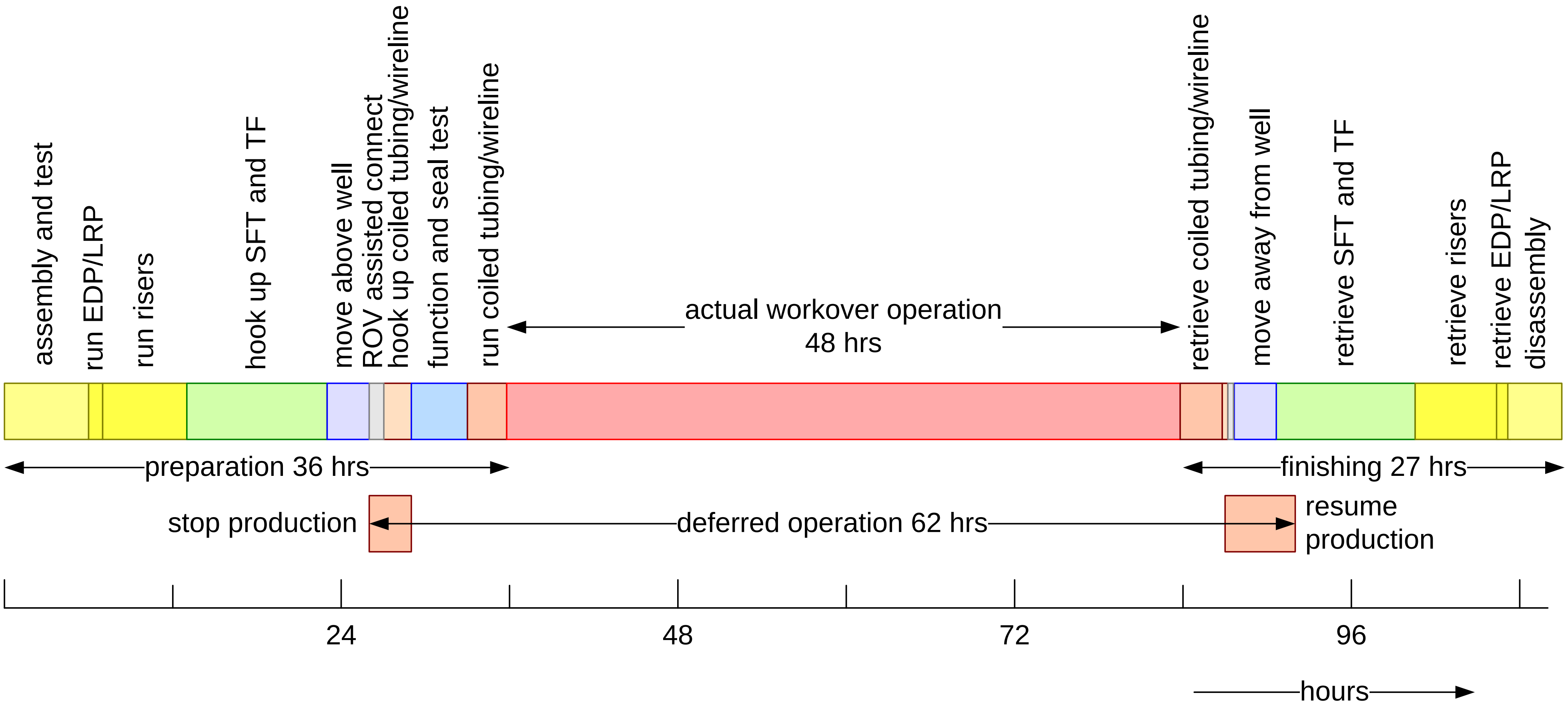
Workflow as Timeline

assumptions:

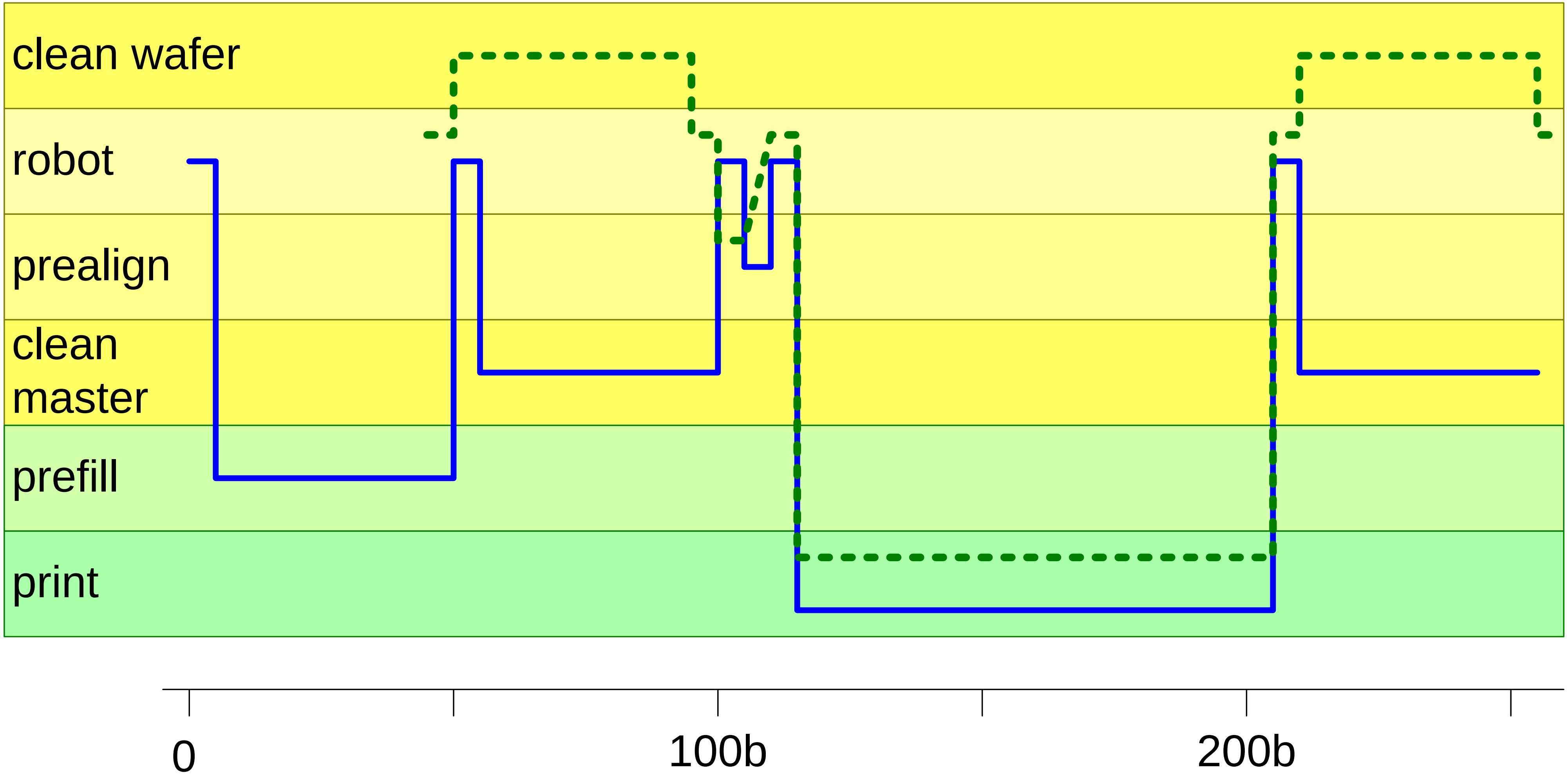
running and retrieving risers: 50m/hr

running and retrieving coiled tubing/wireline: 100m/hr

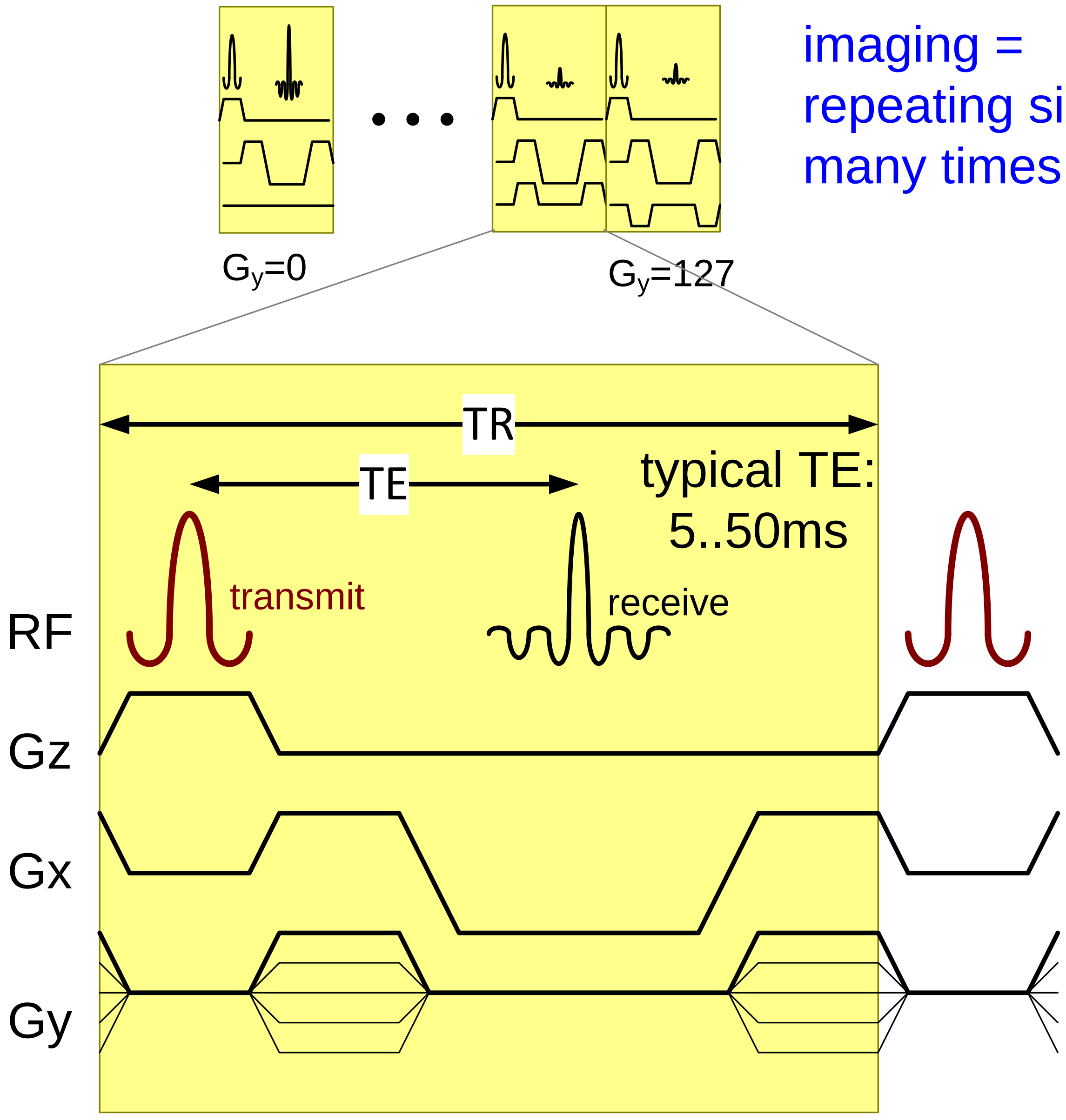
depth: 300m



Swimming Lane Example

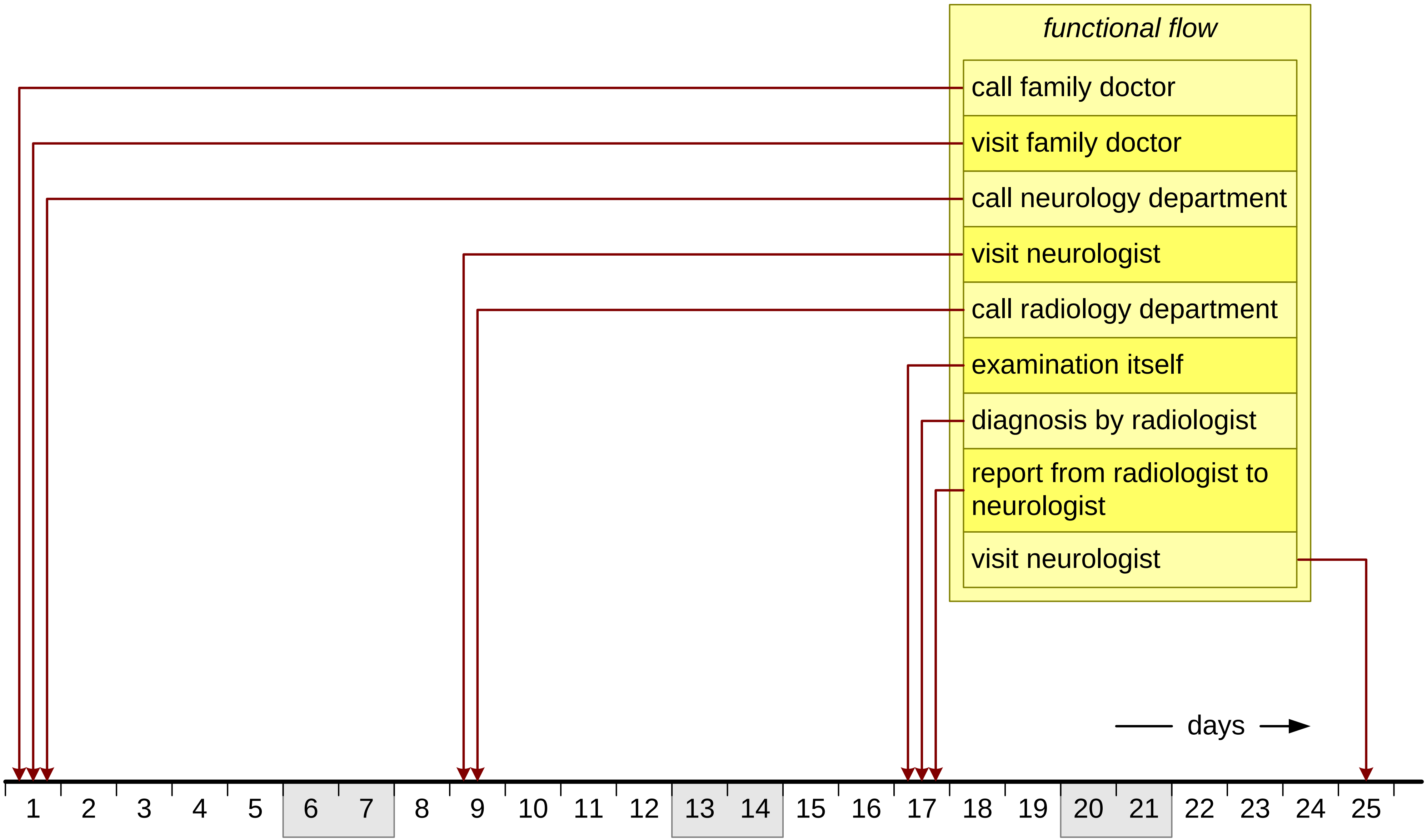


Example Signal Waveforms

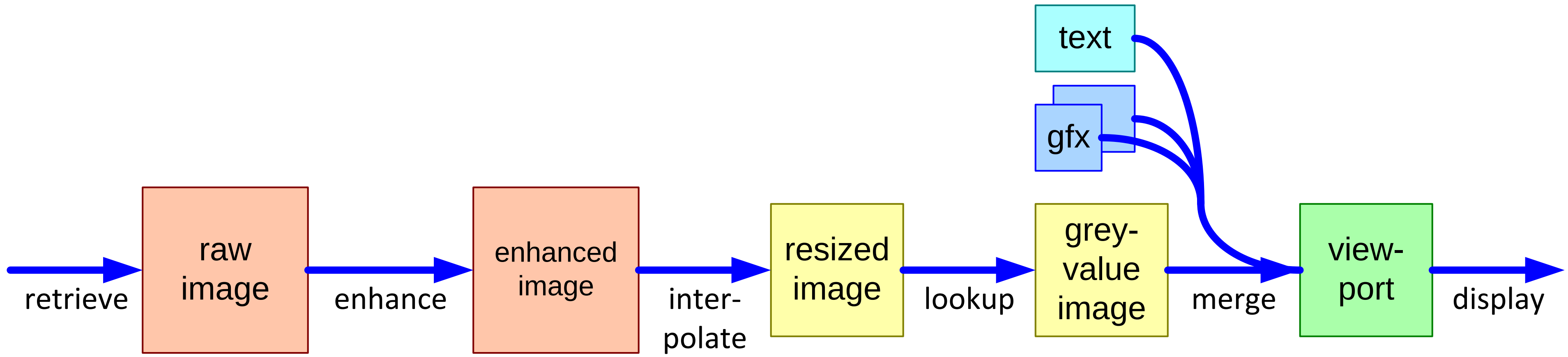


imaging =
repeating similar pattern
many times

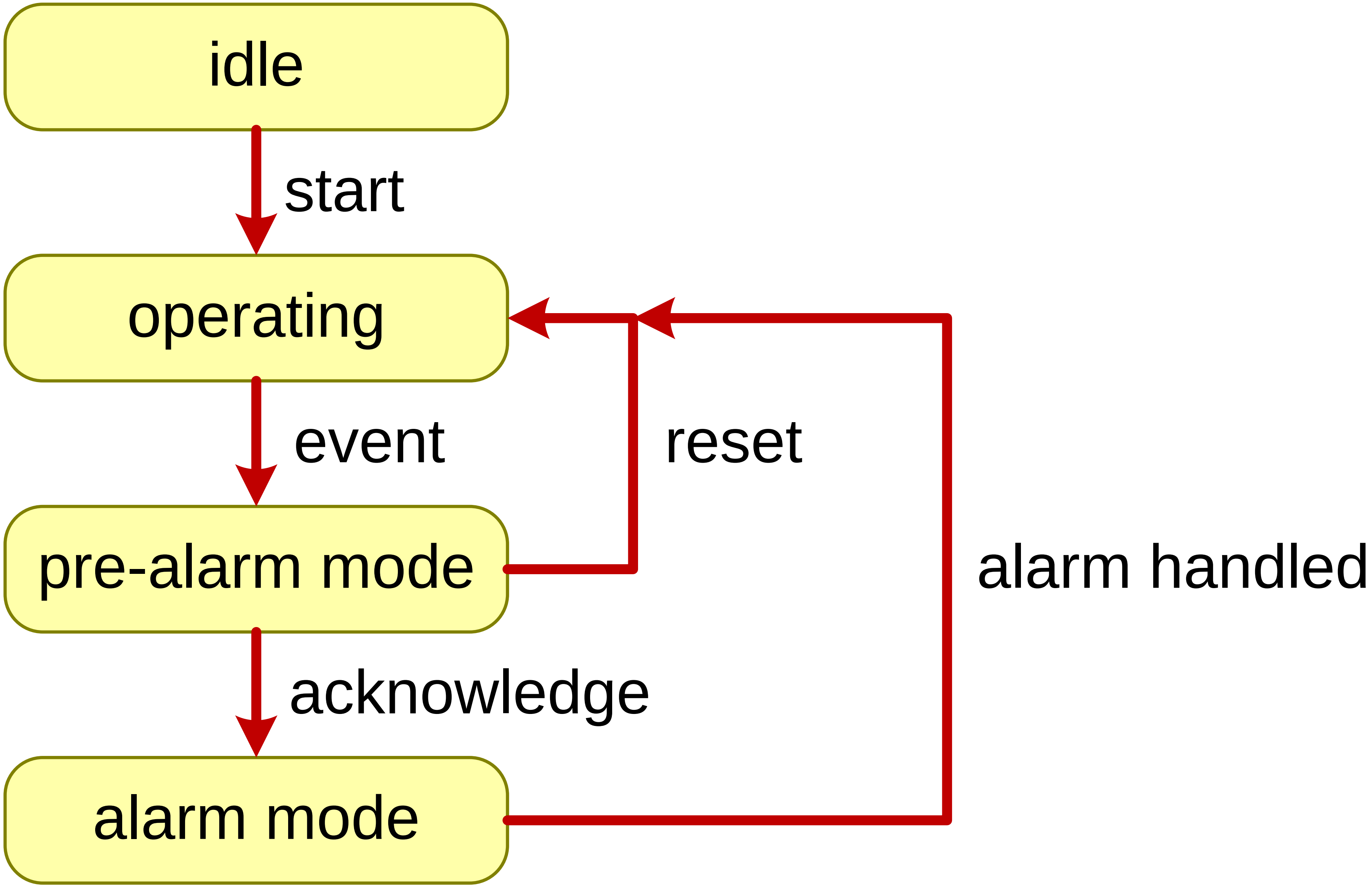
Example Time Line with Functional Model



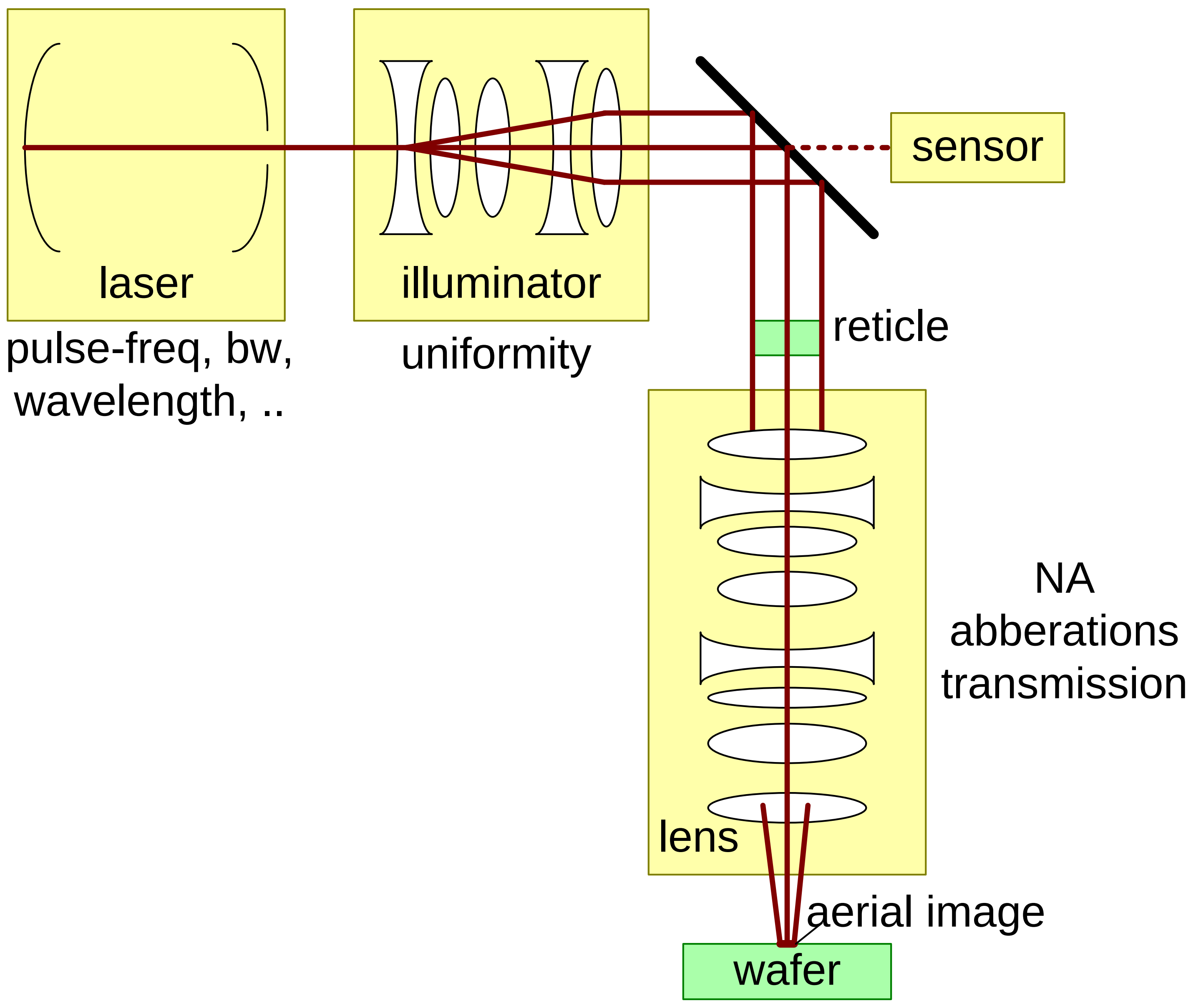
Information Centric Processing Diagram



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

version: 0
July 3, 2023
VDBkeyPhrases

Exercise Dynamic Behavior

Capture the **dynamic behavior** of the **internals** of your system in **multiple** diagrams.

Diagrams that capture dynamic behavior are among others:

- Functional flow (of control or information, material or goods, or energy)
- Activity or sequence diagrams (e.g. with “swimming lanes”)
- State diagrams

Exercise Block Diagram

Make a set of **block diagrams** capturing the **static parts** and **interfaces**.

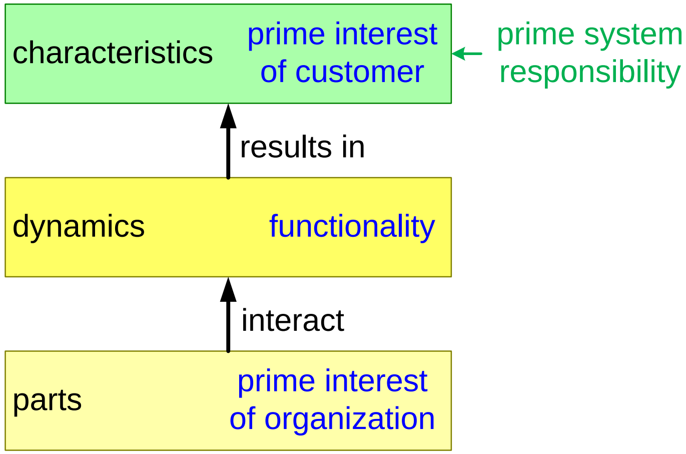
Ensure coverage of the entire system, e.g. including service, training, production, etc.

Show both **hardware** and **software**

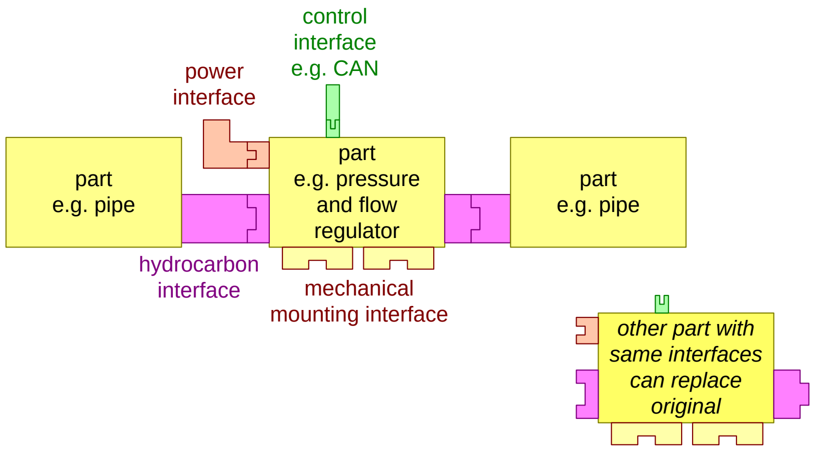
Good block diagrams have in the order of 10 to 20 blocks

Design Fundamentals

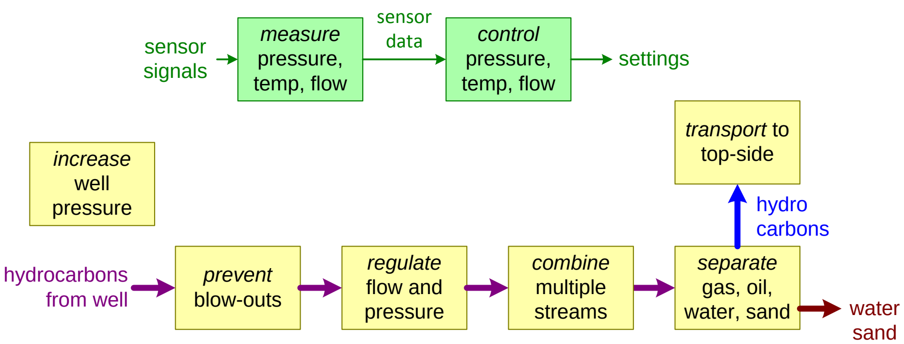
Parts, Dynamics, Characteristics



Decoupling via Interfaces

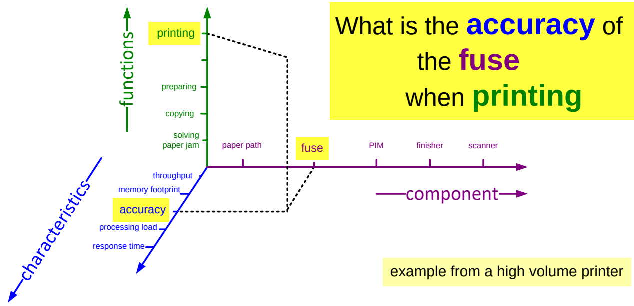


Dynamic Behavior



Question Generator

How about the **<characteristic>**
of the **<component>**
when performing **<function>**?



Module 34, Architectural Reasoning Customer Space Analysis

by *Gerrit Muller* University of South-Eastern Norway-NISE
e-mail: gaudisite@gmail.com
www.gaudisite.nl

Abstract

This module provides methods and techniques to analyze the customer space.

Distribution

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version: 1.1

Methods to Explore the Customer Perspective

by *Gerrit Muller* University of South-Eastern Norway
e-mail: gaudisite@gmail.com
www.gaudisite.nl

Abstract

This presentation provides a set of techniques to explore the customer perspective. The main purpose is for an organization to understand its customer sufficiently. Architects need this level of understanding to guide specification and design.

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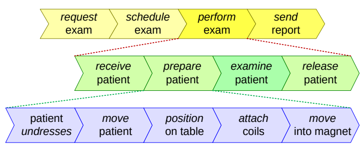
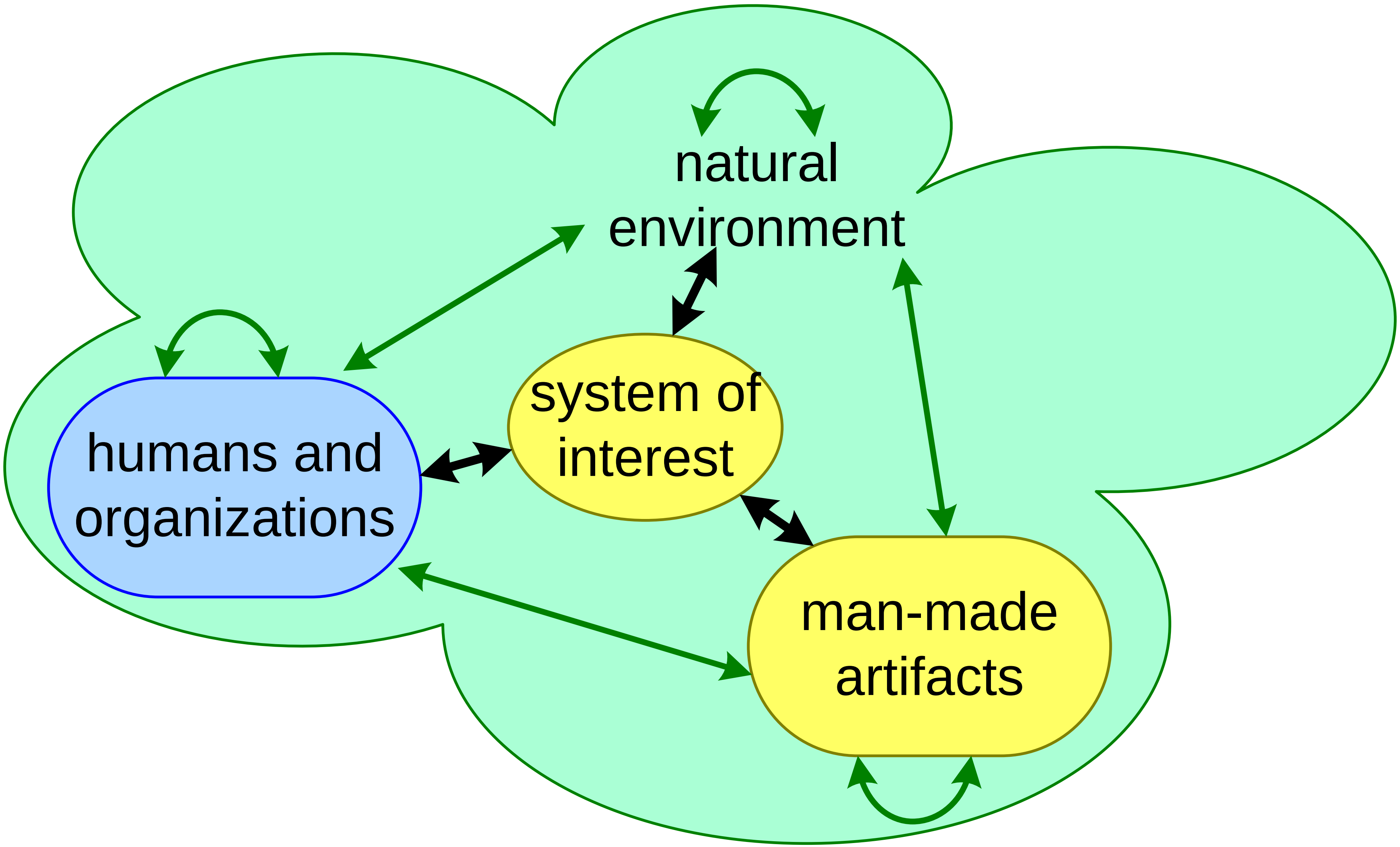


Overview of methods

what	story telling, scenario	http://www.gaudisite.nl/info/StoryHowTo.info.html	
who	stakeholders and concerns	*humans* *organizations*	autonomous behavior emotions
how	system context diagram	*human-made artifacts*	
	workflow		
when	timeline	from seconds to years	
where	map	from nanometers to kilometers	
why	customer key driver graph	http://www.gaudisite.nl/info/KeyDriversHowTo.info.html	
financial	productivity model cost of ownership model money flow		

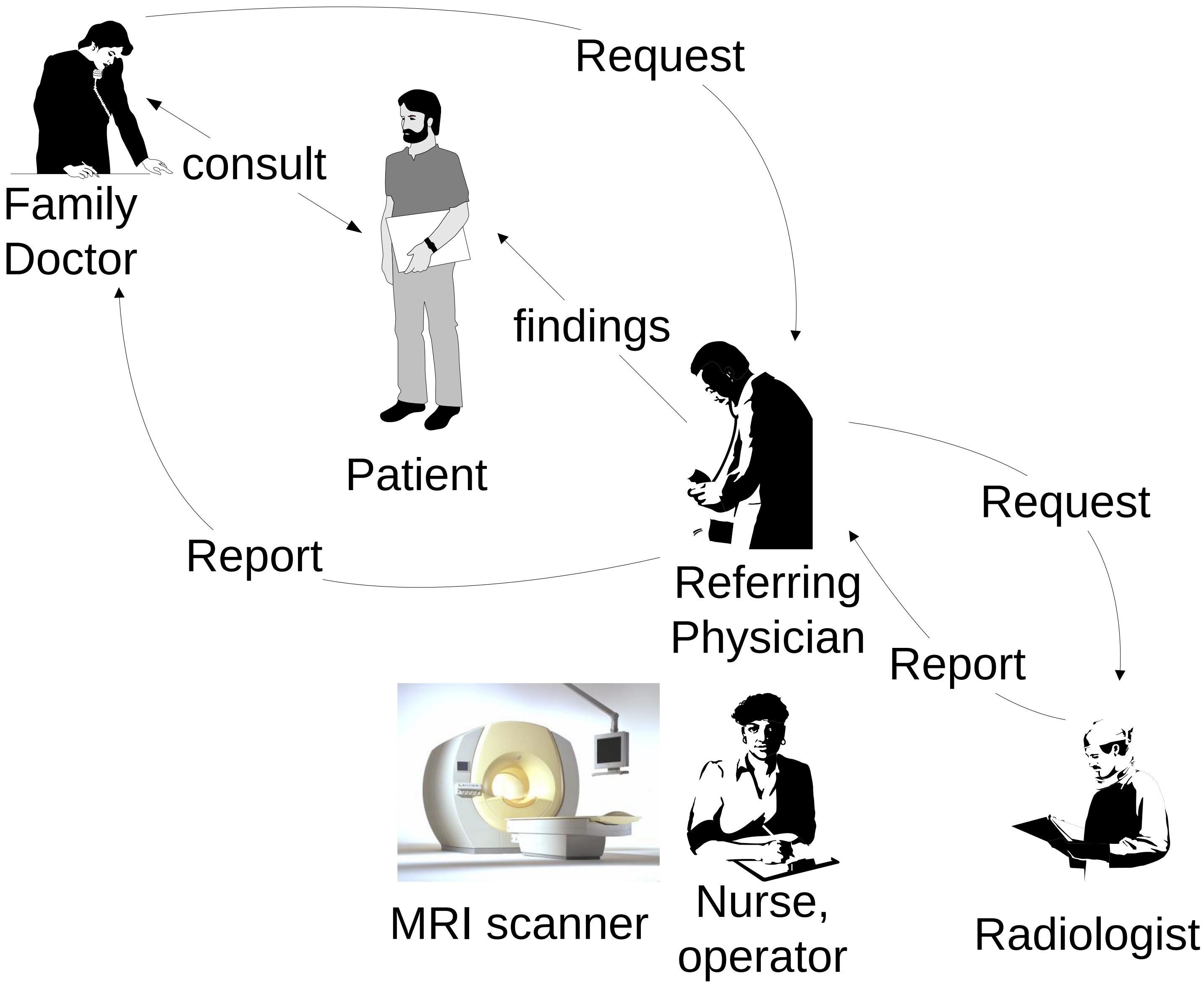
Various Perspectives on Context



Scenario: Patient George

- Patient George has continuous headache.
- His family doctor has send him to the Neurologist.
- The Neurologist wants to exclude the possibility of a tumor and requests an MRI examination.
- The Radiologists does not see any indication for a tumor.
- The Radiologist sends his report to the Neurologist.
- The Neurologist discusses his findings with the patient and sends a report to the family doctor.

From Complaint to Diagnosis



Stakeholders and concerns MRI scanner

government
cost of care

financial dir.
cash flow
cost of op.

insurance
cost of care

administration
patient id
invoice

general practitioner
patient

ref. physician
diagnosis
treatment

radiologist
diagnosis
reimburstment

nurse
patient
ease of work

patient
comfort
health

inspection
quality

family
support

operator
ease of use

IT dep.
conformance
security

facility man.
space
service supp.

maintainer
accessibility
safety

cleaner
accessibility
safety

legend

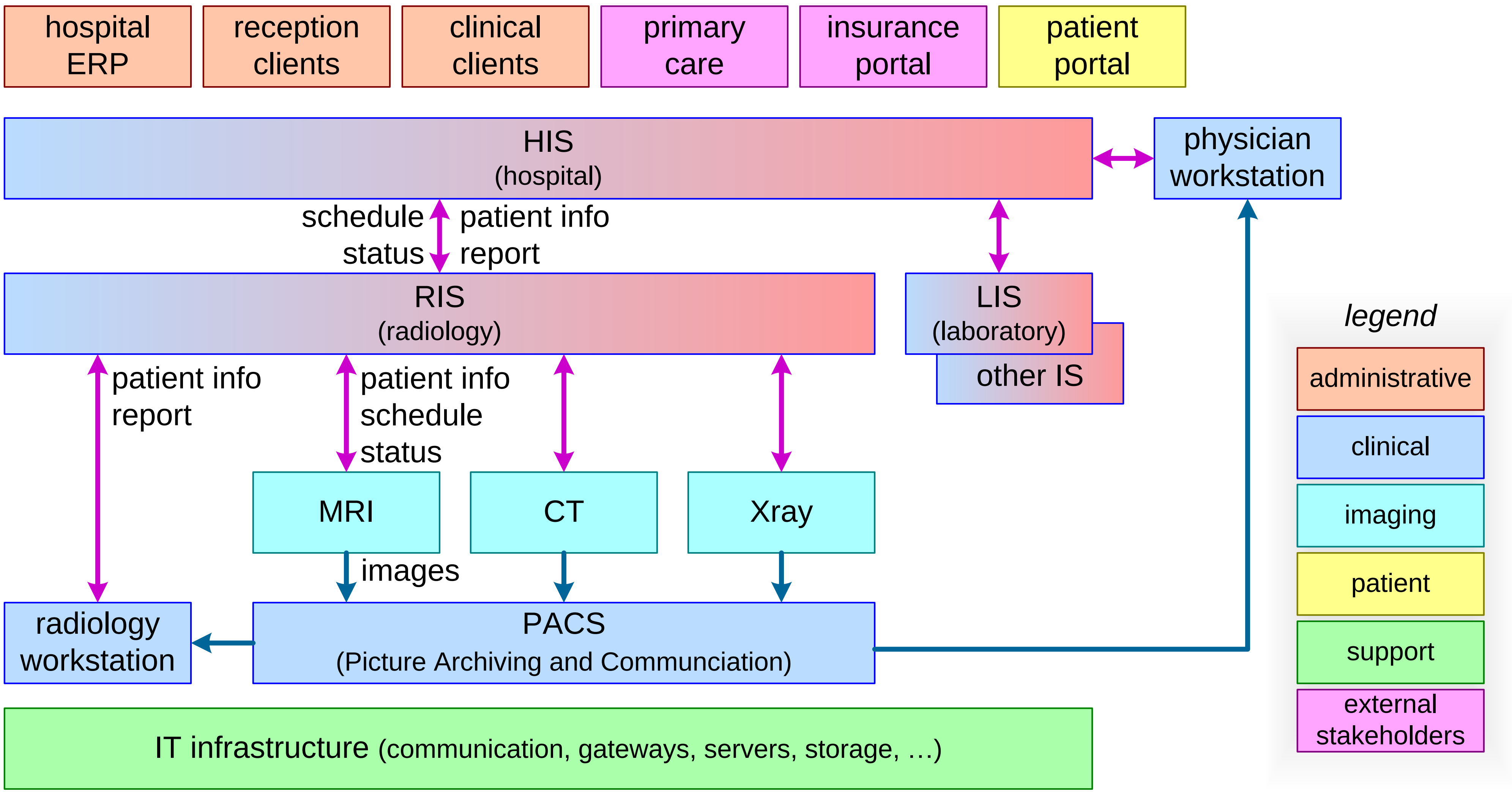
administrative

clinical

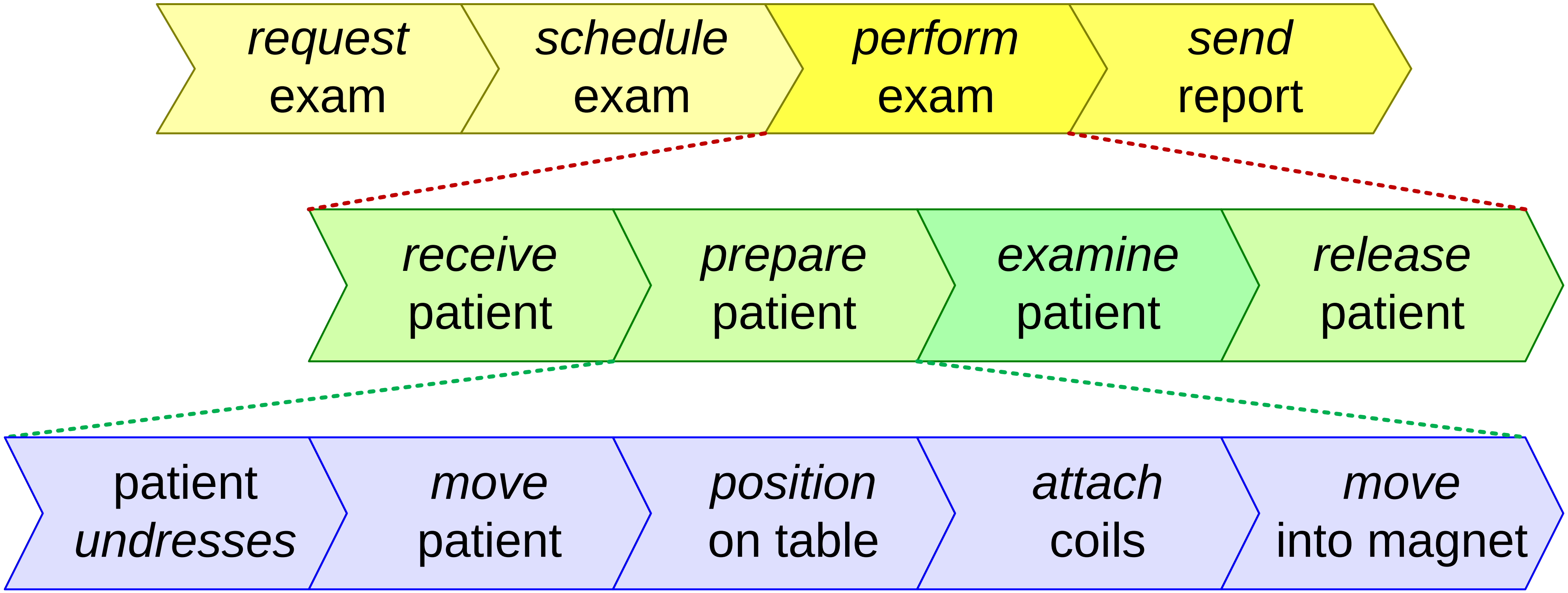
patient

support

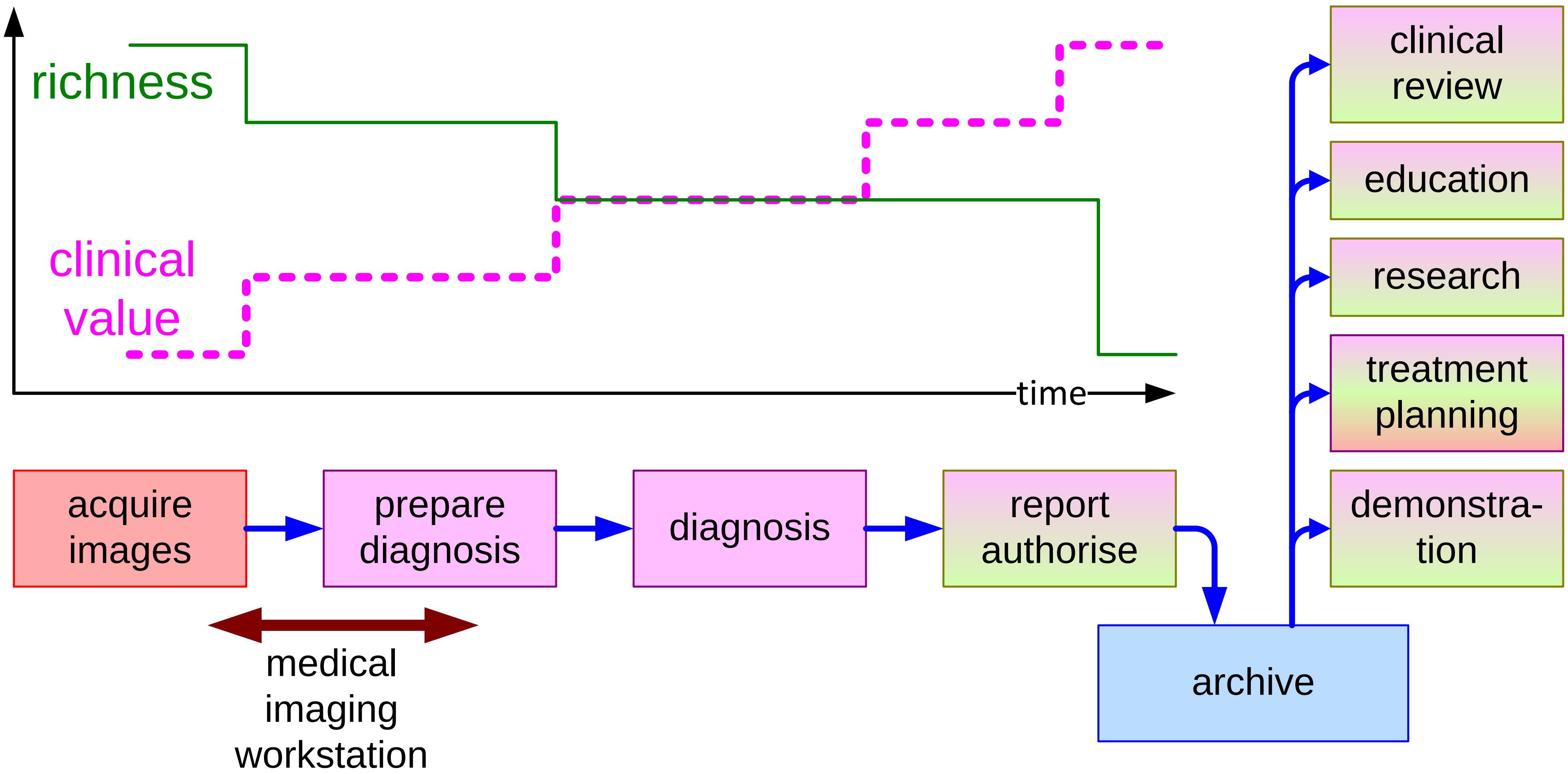
Context of MRI



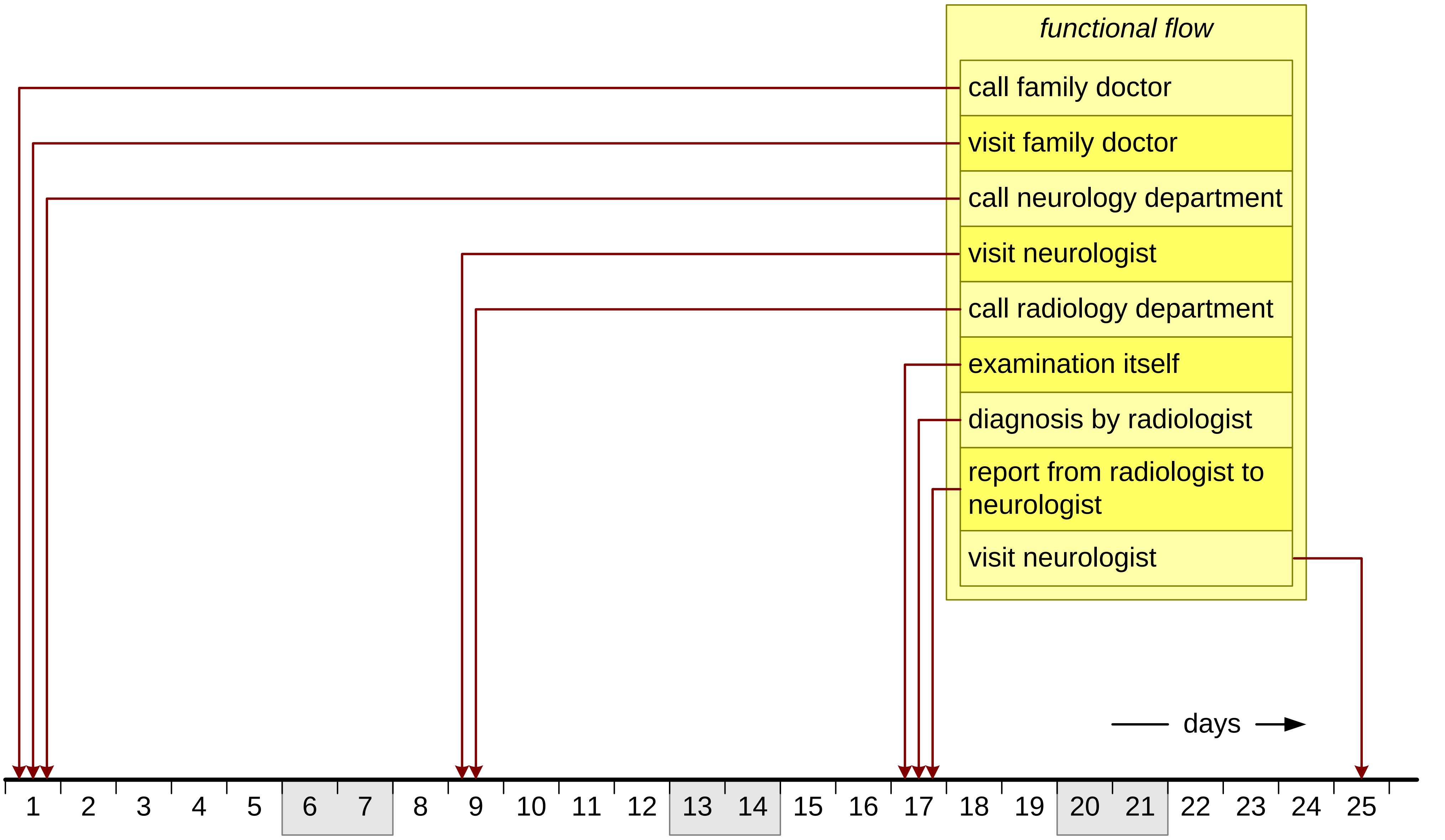
Workflow


request exam
schedule exam
perform exam
send report
receive patient
prepare patient
examine patient
release patient
patient undresses
move patient
position on table
attach coils
move into magnet

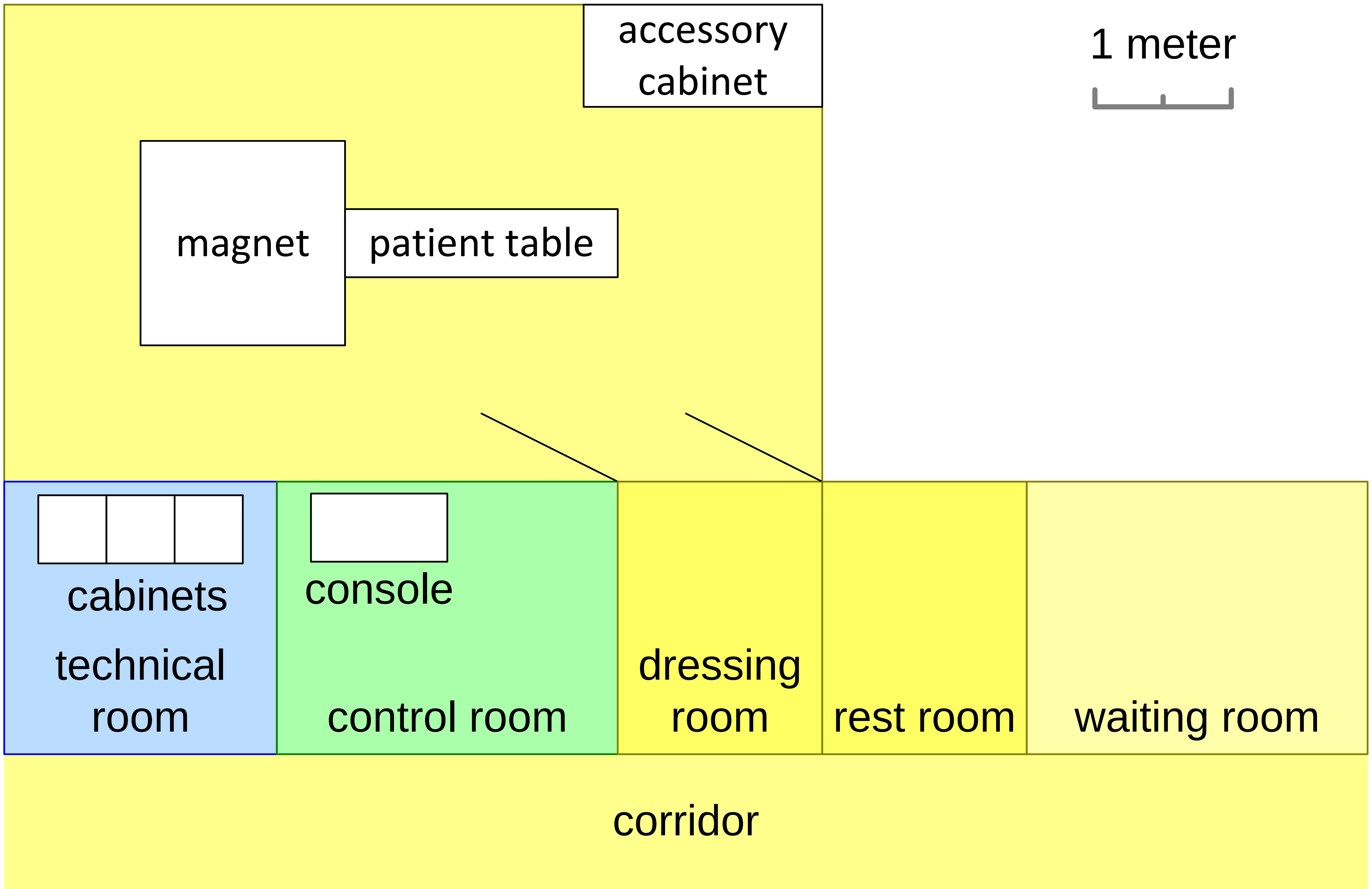
Clinical Information Flow



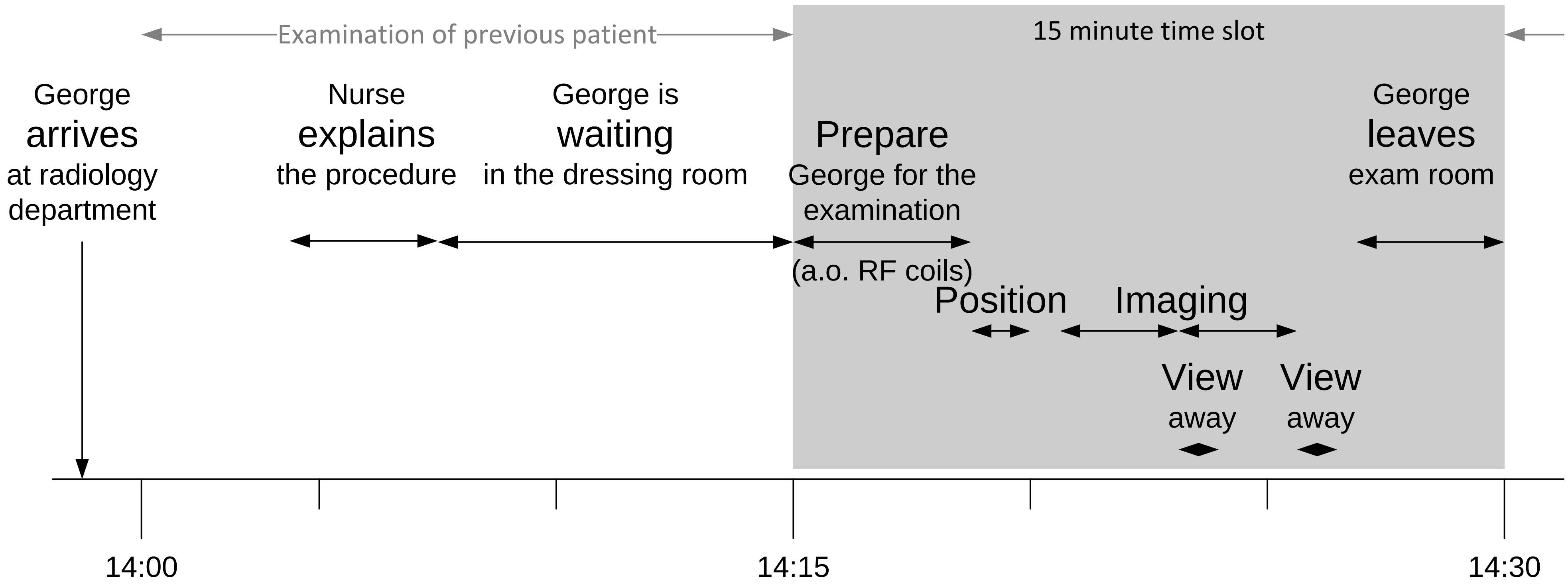
weeks view: from Complaint to Diagnosis



Room Layout


accessory cabinet
1 meter
magnet
patient table
cabinets
technical room
console
control room
dressing room
rest room
waiting room
corridor

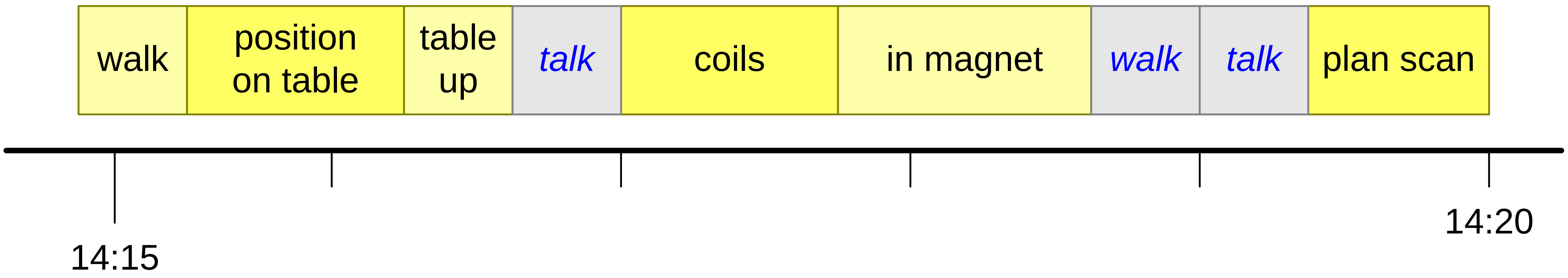
half hour view: Examination



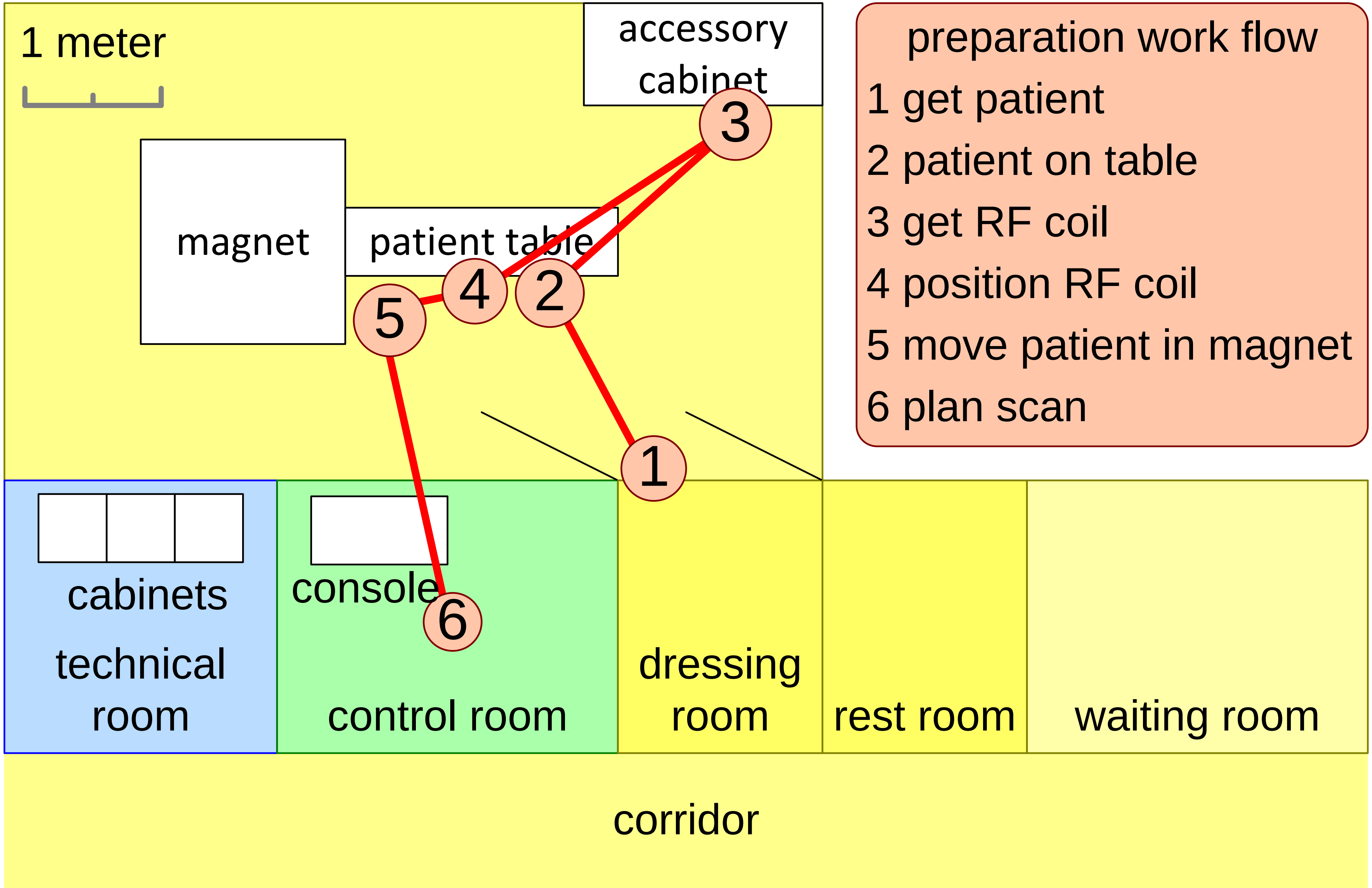
5 minute view: Patient Preparation (1 operator)

functional procedure

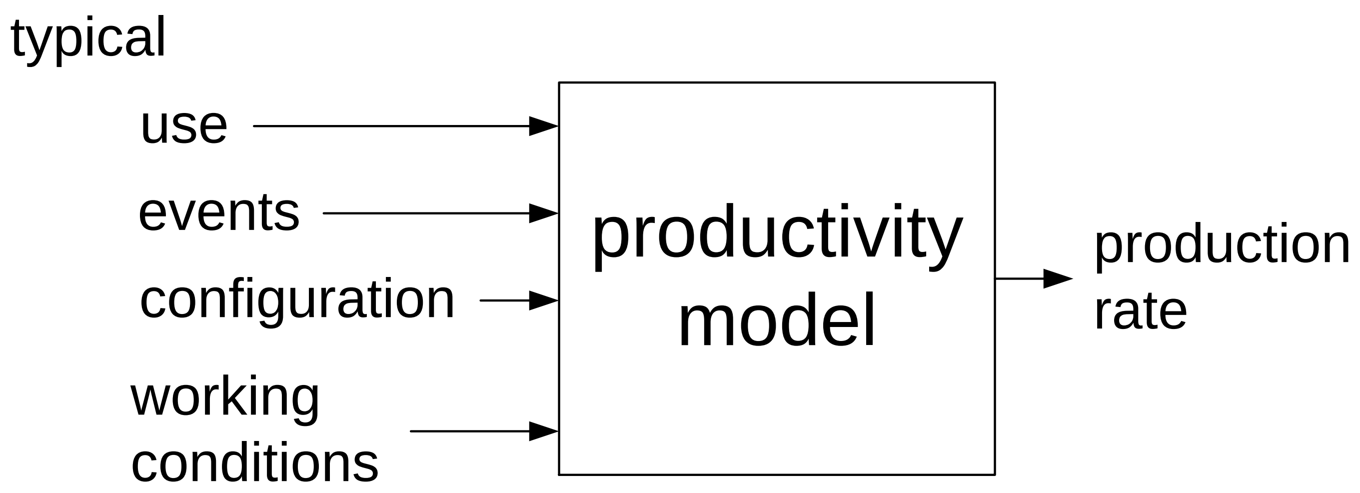
- walk from dressing room to table
- position patient on table
- move table upwards
- position coils and connect
- move table and patient into magnet
- make plan scan

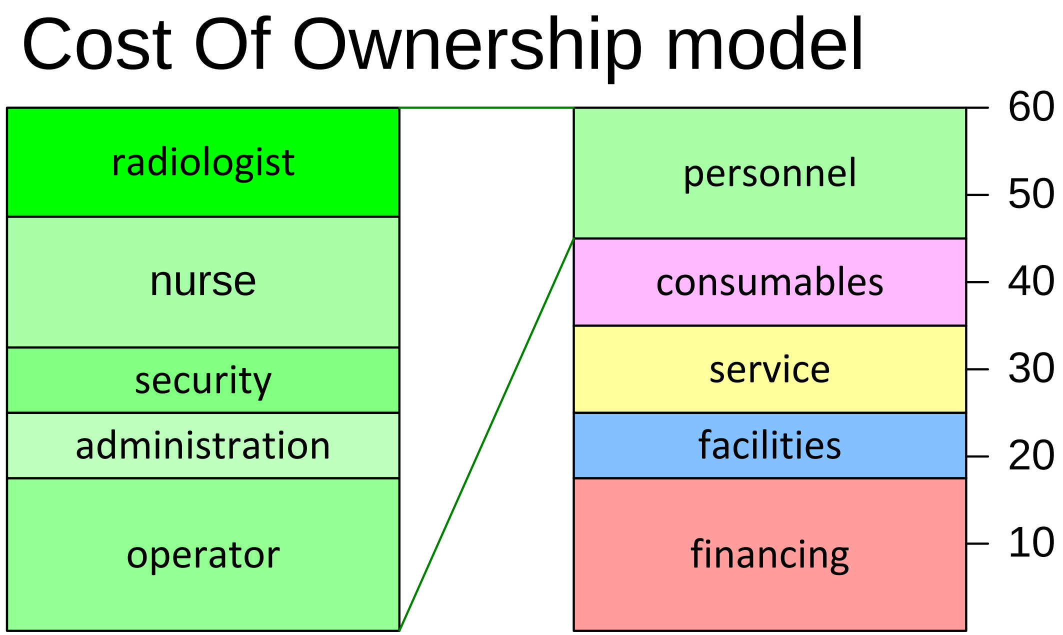


Patient Preparation Work Flow

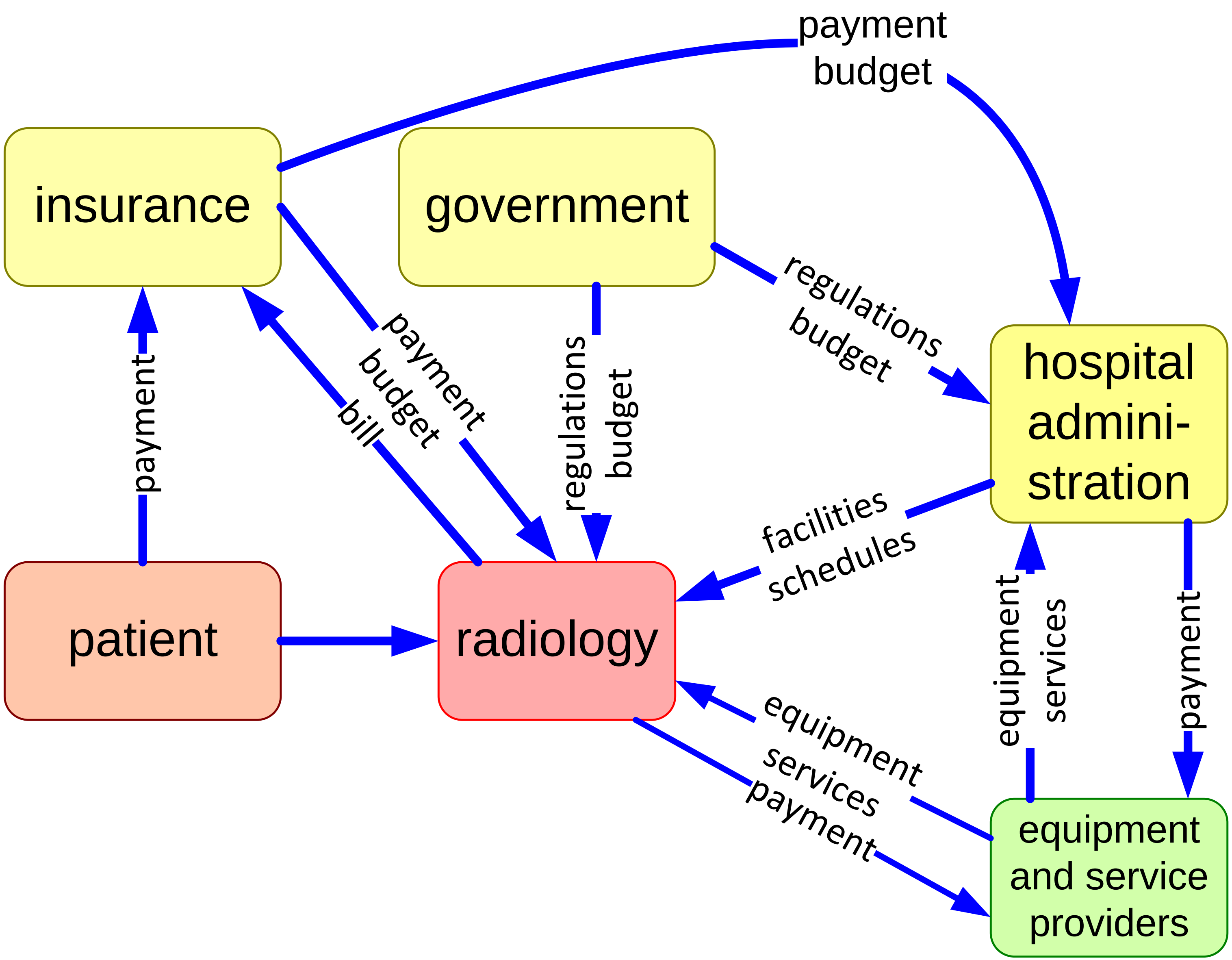


Productivity and Cost models





The financial context of the radiology department



Make a **context diagram**, showing the **systems** and their **relations** in the **customer space**

- typically, tens of systems are relevant for customers

Capture one or a few main **workflows** in the customer space

Key Drivers How To

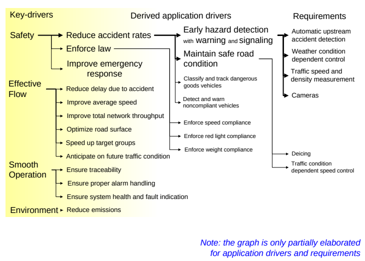
by *Gerrit Muller* University of South-Eastern Norway-NISE

e-mail: gaudisite@gmail.com

www.gaudisite.nl

Abstract

The notion of ”business key drivers” is introduced and a method is described to link these key drivers to the product specification.



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July 3, 2023
status: draft
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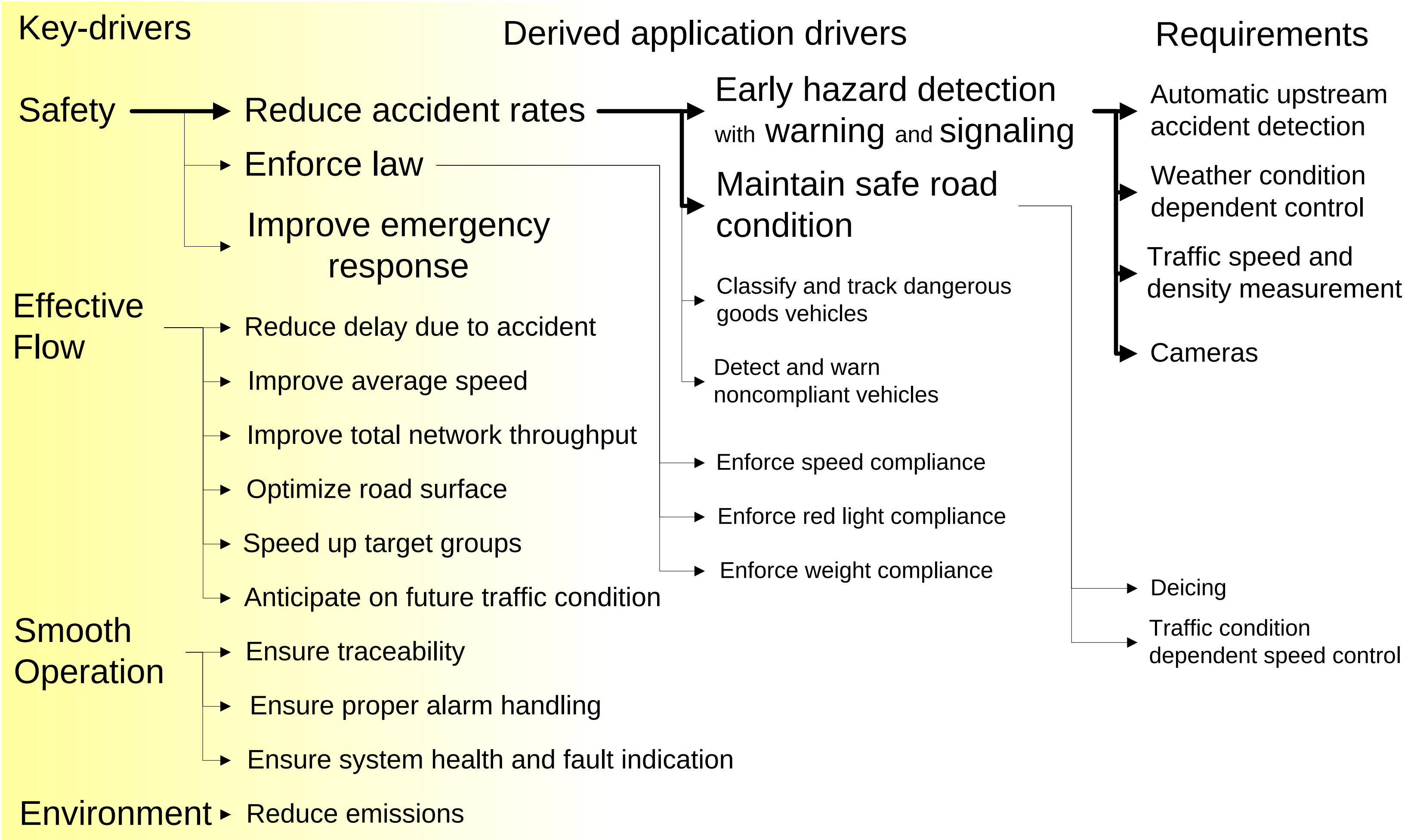
Example Motorway Management Analysis



Note: the graph is only partially elaborated for application drivers and requirements

Method to create Key Driver Graph

• Define the scope specific.	in terms of stakeholder or market segments
• Acquire and analyze facts	extract facts from the product specification and ask why questions about the specification of existing products.
• Build a graph of relations between drivers and requirements by means of brainstorming and discussions	where requirements may have multiple drivers
• Obtain feedback	discuss with customers, observe their reactions
• Iterate many times	increased understanding often triggers the move of issues from driver to requirement or vice versa and rephrasing

Recommendation for the Definition of Key Drivers

• Limit the number of key-drivers	minimal 3, maximal 6
• Don't leave out the obvious key-drivers	for instance the well-known main function of the product
• Use short names, recognized by the customer.	
• Use market-/customer- specific names, no generic names	for instance replace "ease of use" by "minimal number of actions for experienced users", or "efficiency" by "integral cost per patient"
• Do not worry about the exact boundary between Customer Objective and Application	create clear goal means relations

Transformation of Key Drivers into Requirements

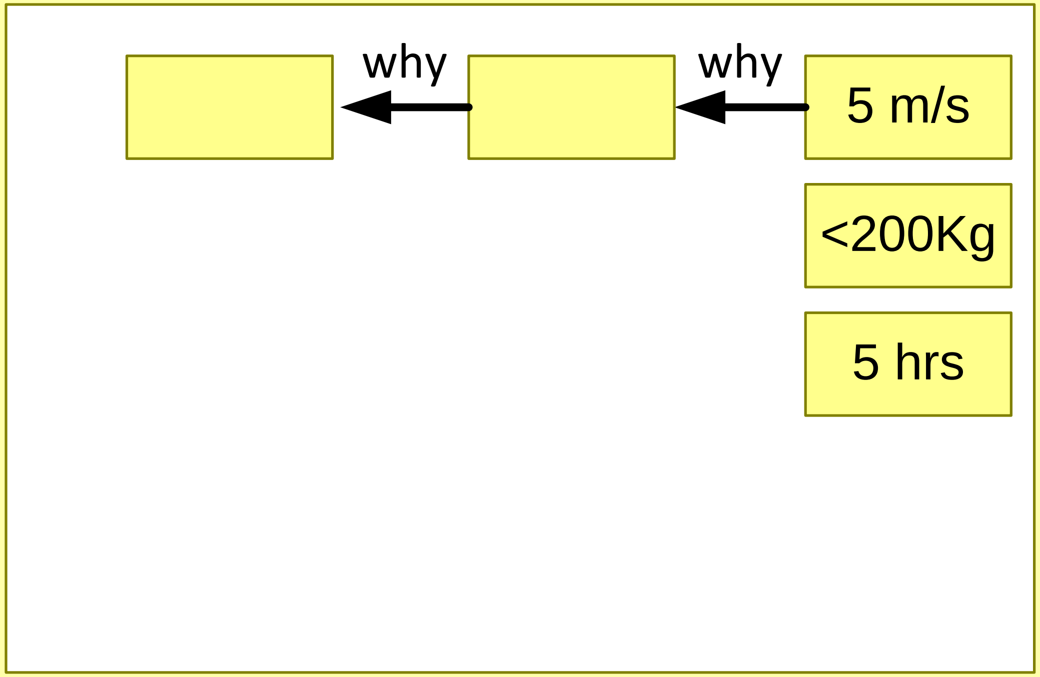
Customer **What**	Customer **How**	Product **What**
Customer objectives	**A**pplication	**F**unctional
Key (Customer) Drivers →	Derived Application Drivers →	Requirements
goal	means may be skipped or articulated by several intermediate steps	functions interfaces performance figures

Exercise Customer Key Driver Graph

Make a **customer key driver graph**

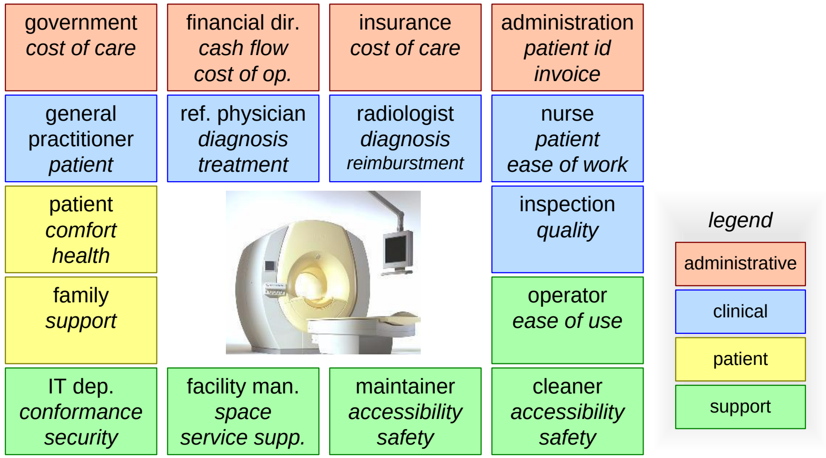
Use yellow note stickers

Start at the right hand side

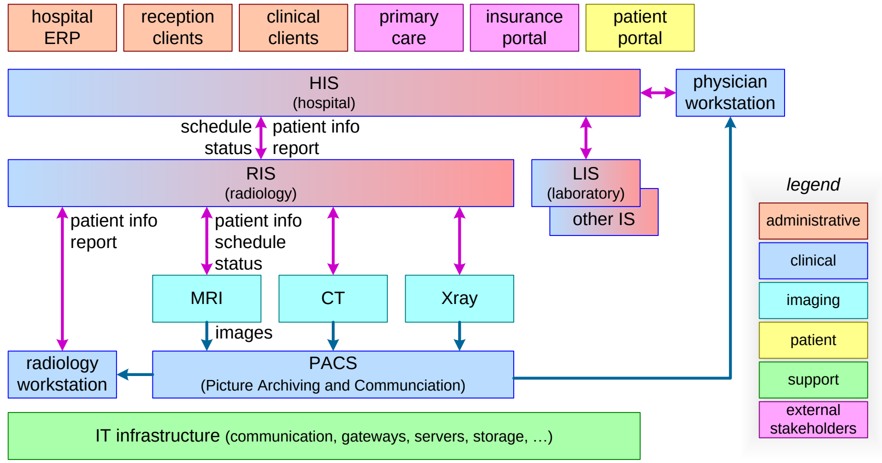


Analysis Methods and Techniques

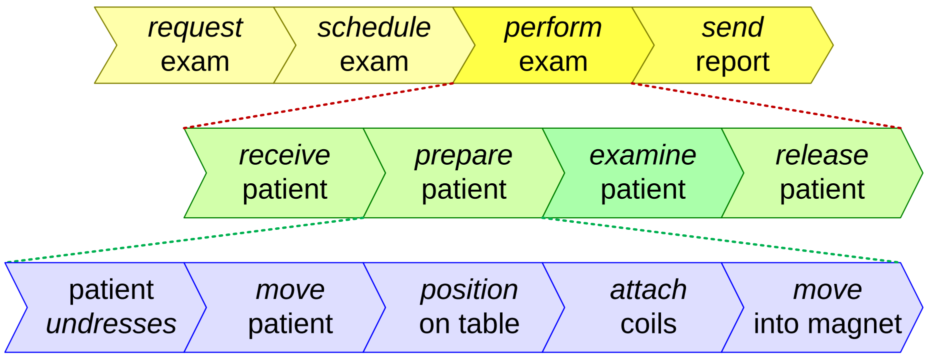
Stakeholders and Concerns (Who)



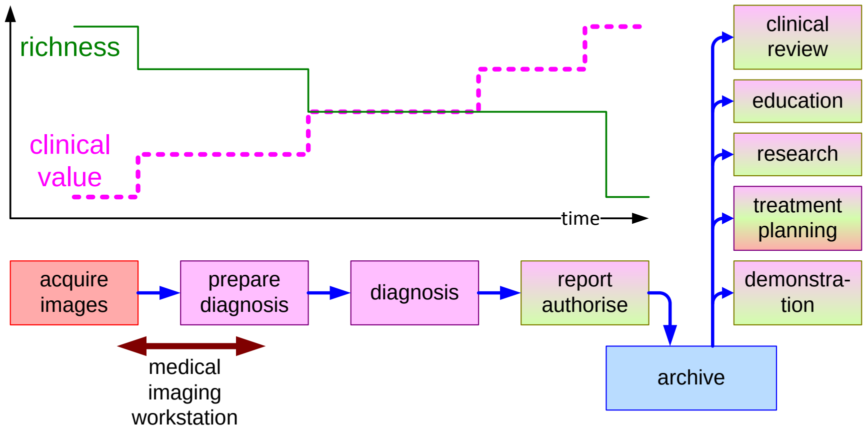
Context Diagram (what sytems)



Workflow (what dynamics)

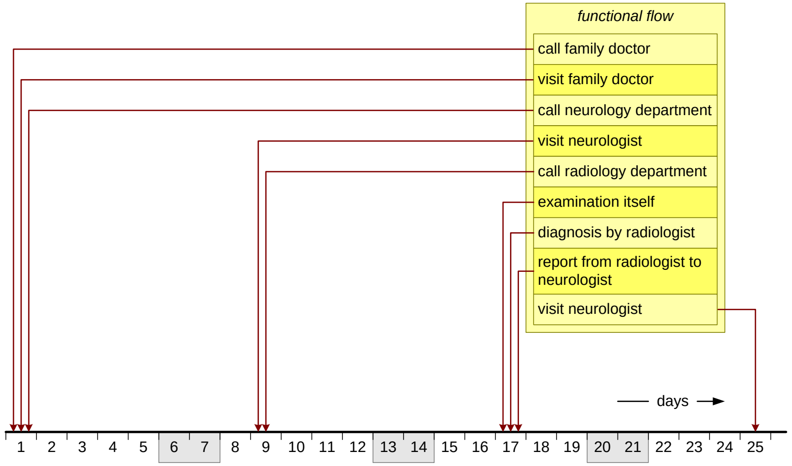


Information Flow

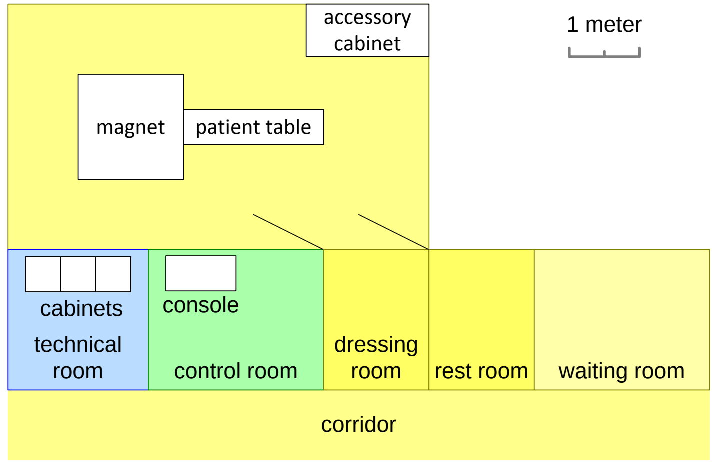


More Analysis Methods and Techniques

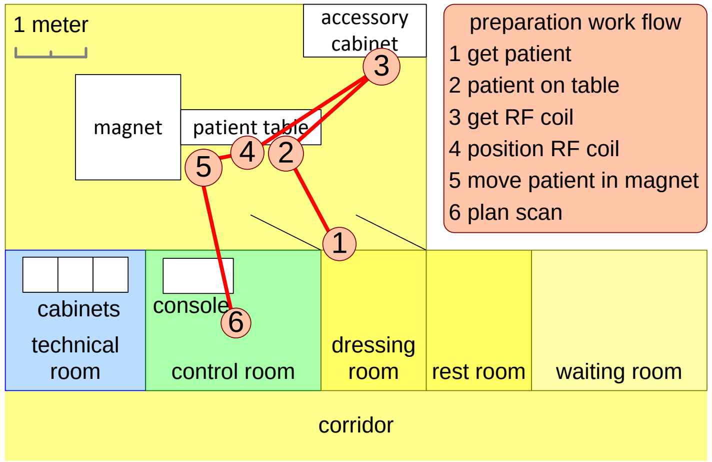
Timeline (when, what, who)



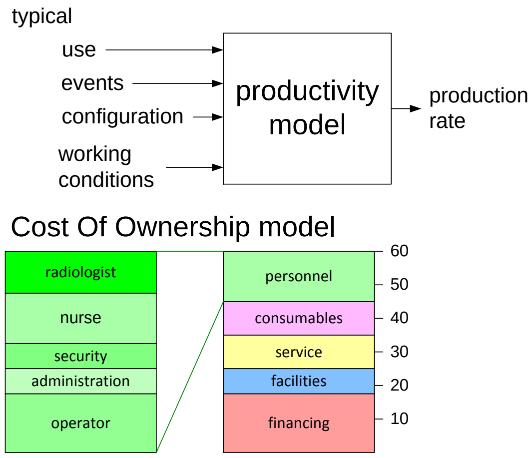
2D or 3D map (where)



Annotated map (where, what)

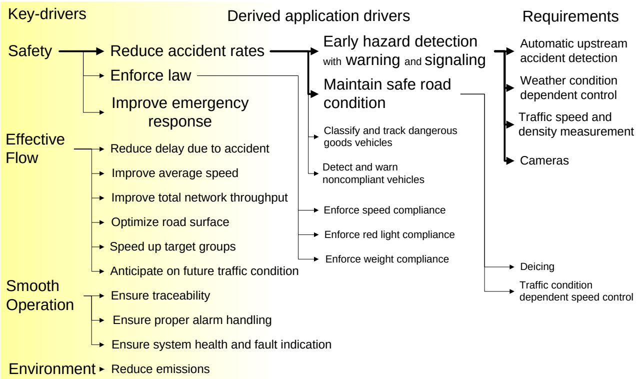


Cost Models



Customer Key Driver Graph

Focus on Customer World



Note: the graph is only partially elaborated for application drivers and requirements

Specific Scope, Fact Based

• Define the scope specific.	in terms of stakeholder or market segments
• Acquire and analyze facts	extract facts from the product specification and ask why questions about the specification of existing products.
• Build a graph of relations between drivers and requirements by means of brainstorming and discussions	where requirements may have multiple drivers
• Obtain feedback	discuss with customers, observe their reactions
• Iterate many times	increased understanding often triggers the move of issues from driver to requirement or vice versa and rephrasing

3 to 6 Key driver, Capture Tensions

• Limit the number of key-drivers	minimal 3, maximal 6
• Don't leave out the obvious key-drivers	for instance the well-known main function of the product
• Use short names, recognized by the customer.	
• Use market-/customer- specific names, no generic names	for instance replace "ease of use" by "minimal number of actions for experienced users", or "efficiency" by "integral cost per patient"
• Do not worry about the exact boundary between Customer Objective and Application	create clear goal means relations

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Module 31, Architectural Reasoning Conceptual Design

by *Gerrit Muller* University of South-Eastern Norway-NISE
e-mail: gaudisite@gmail.com
www.gaudisite.nl

Abstract

This module conceptual design methods, such as budgeting and concept selection.

Distribution

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Modeling and Analysis: Budgeting

by *Gerrit Muller* TNO-ESI, HSN-NISE
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`www.gaudisite.nl`

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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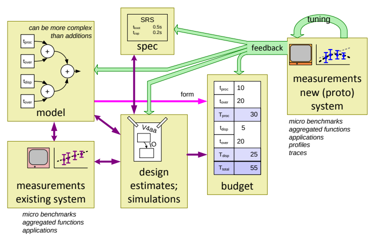


Budgeting

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***

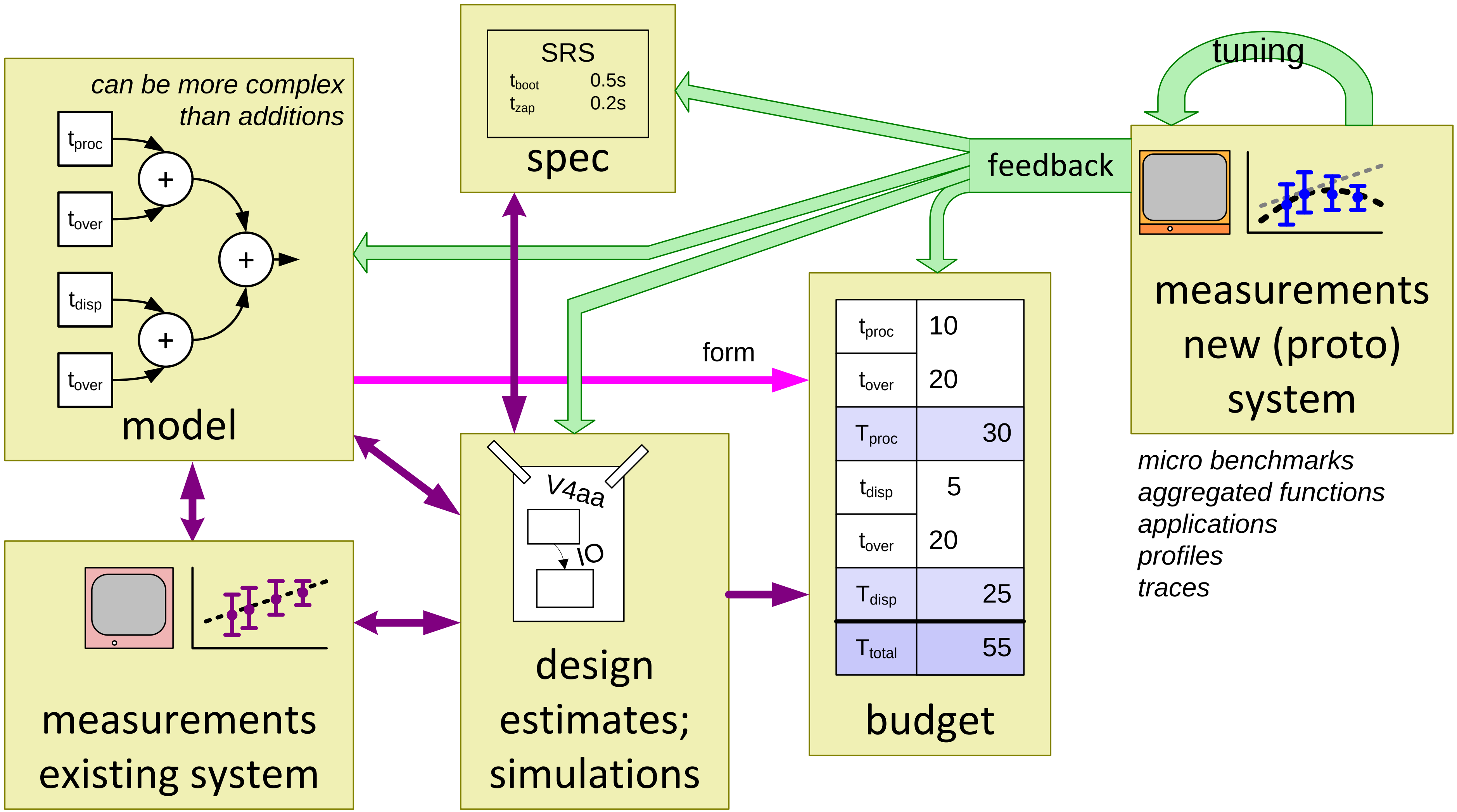
by ***parts*** *of the* ***solution***

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



t_{proc}	10
t_{over}	20
T_{proc}	30
t_{disp}	5
t_{over}	20
T_{disp}	25
T_{total}	55

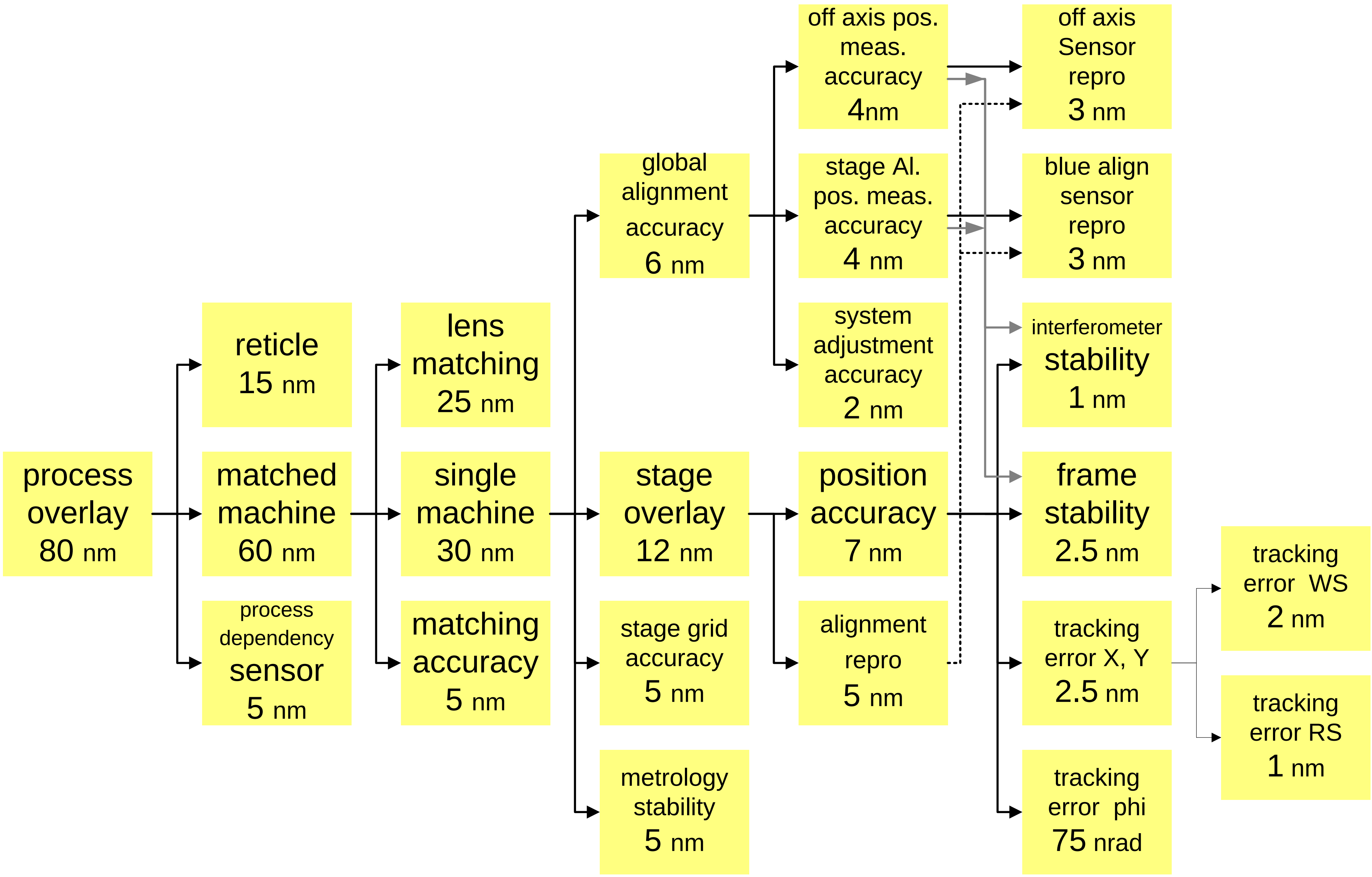
micro benchmarks
aggregated functions
applications
profiles
traces

micro benchmarks
aggregated functions
applications

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	

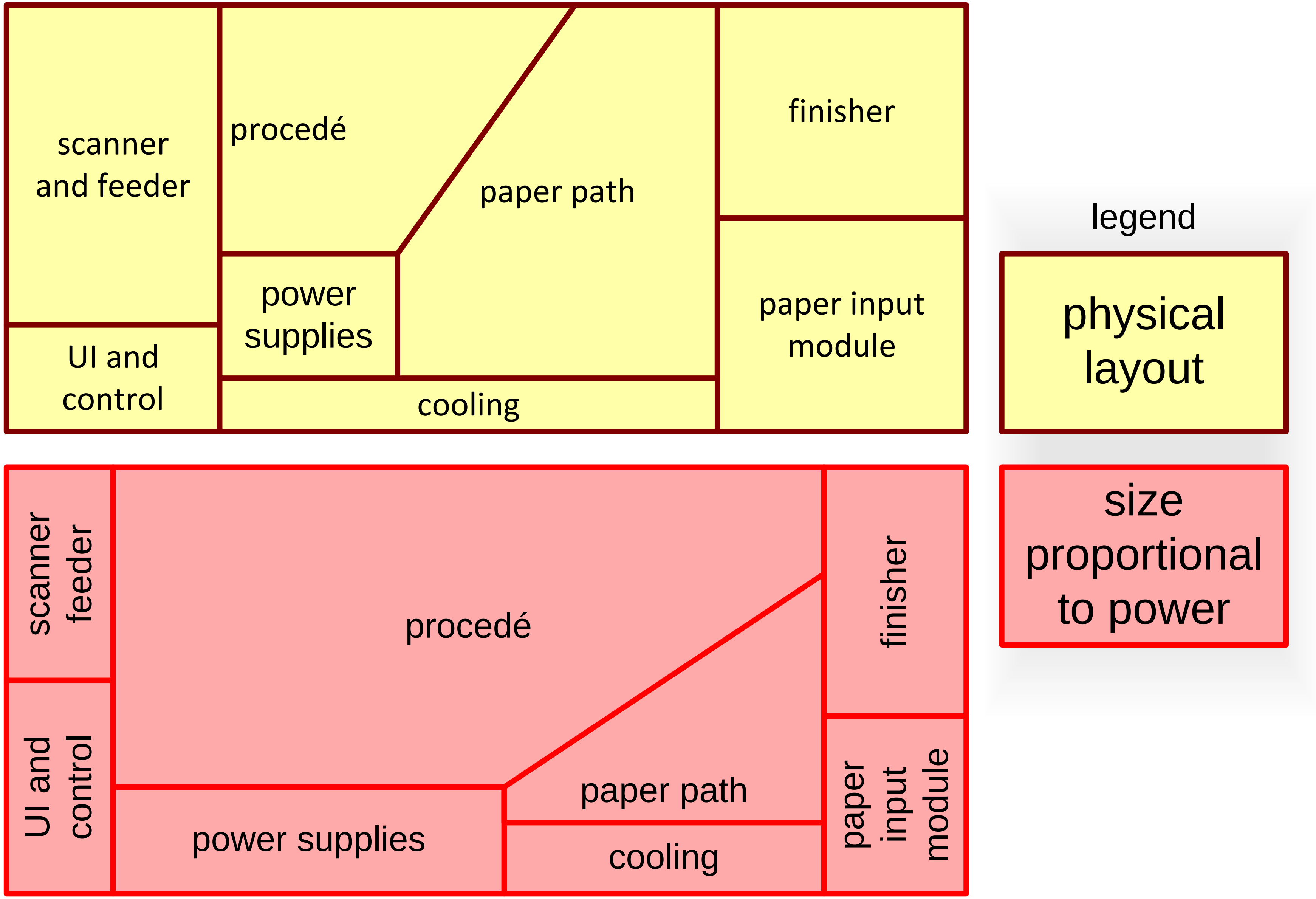
Budgets Applied on Waferstepper Overlay



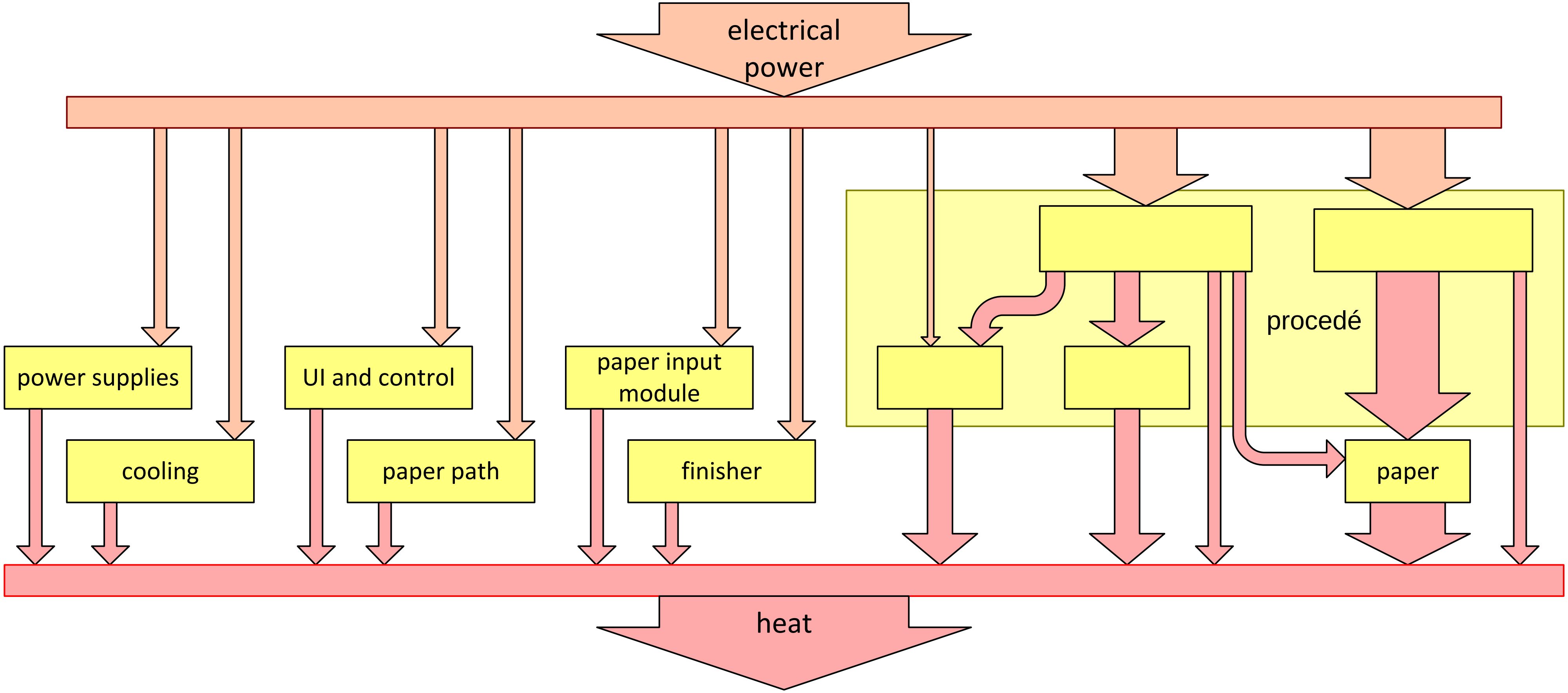
Budgets Applied on Medical Workstation Memory Use

memory budget in Mbytes	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

fact finding through details
aggregate to end-to-end performance
search for appropriate abstraction level(s)

from coarse guesstimate
to reliable prediction

from typical case
to boundaries of requirement space

from static understanding
to dynamic understanding

from steady state
to initialization, state change and shut down

from old system
to prototype
to actual implementation

time

start *later* *only if needed*

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!

Colophon

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.

Exercise Budget

Make a **technical budget** for one of the **key performance parameters**.

- a good budget has 20 to 30 contributing elements
- elements should be balanced (remove or combine insignificant contributions)
- use the previously defined parts and dynamic behavior

Concept Selection, Set Based Design and Late Decision Making

by *Gerrit Muller* University of South-Eastern Norway-NISE
e-mail: gaudisite@gmail.com
www.gaudisite.nl

Abstract

We discuss a systems design approach where several design options are maintained concurrently. In LEAN Product Development this is called set-based design. Concentioanl systems engineering also promotes the concurrent evaluation of multiple concepts, the so-called concept selection. Finally, LEAN product development advocates to keep options open as long as feasible; the so-called late decision making.

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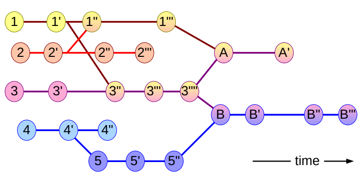
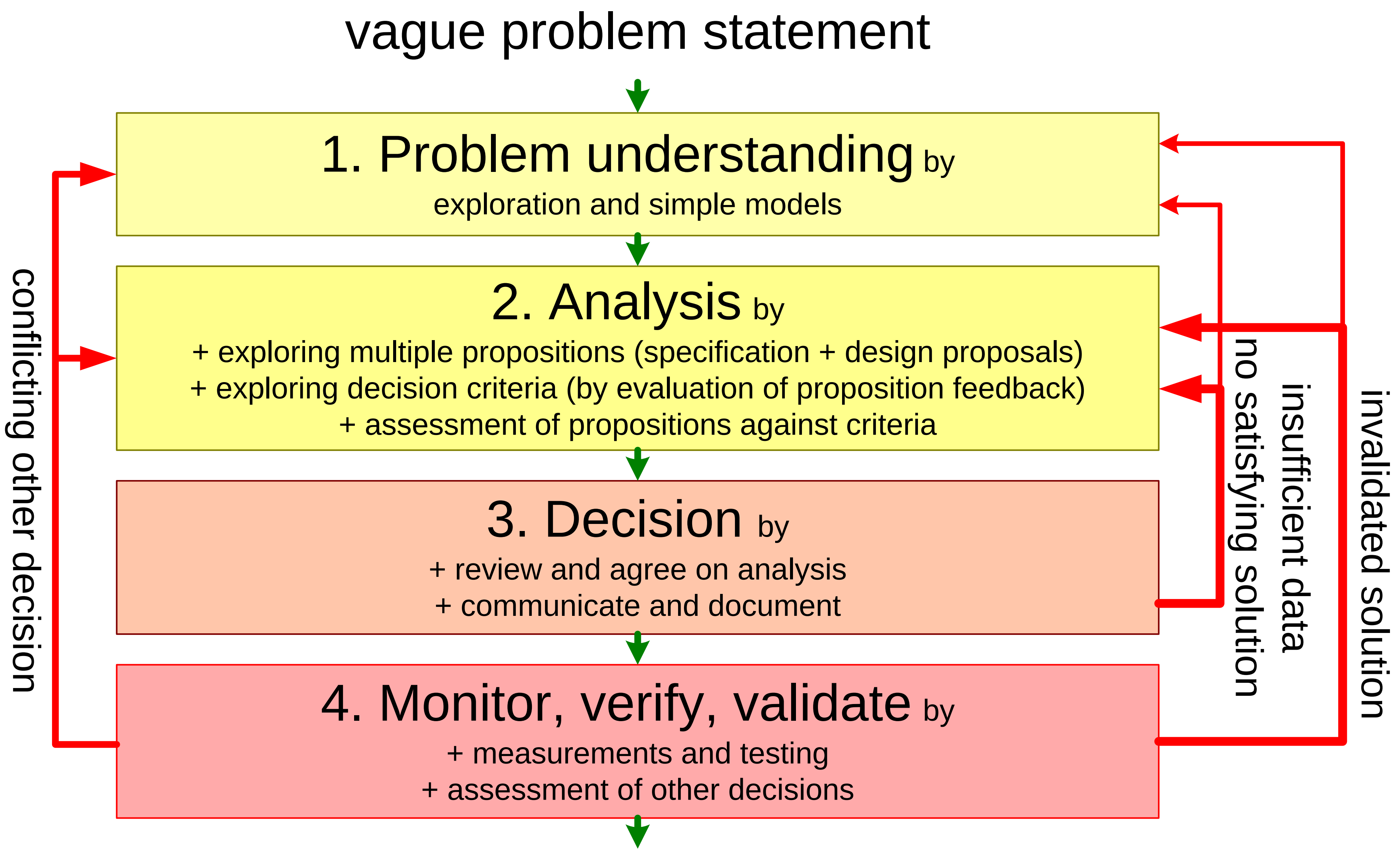
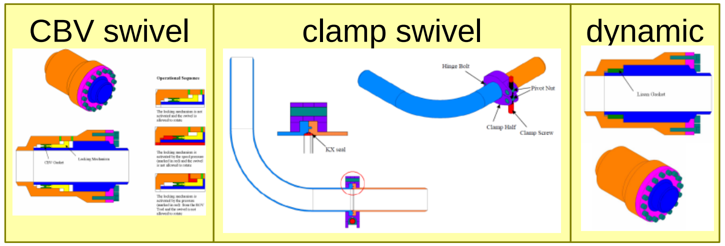


Problem Solving Approach



Examples of Pugh Matrix Application

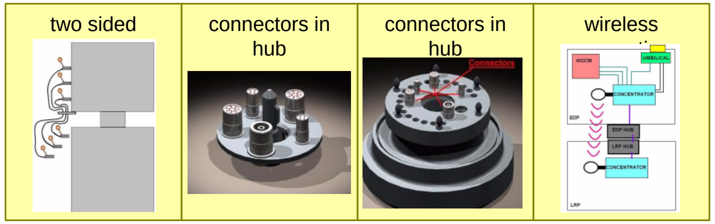
Swivel concept selection



evaluation criteria	weight	CBV		clamp		dynamic	
Maturity	10						
Development level		5	50	2	20	2	50
Cost	20						
Hardware cost		4	80	2	40	5	100
Development cost		5	100	2	40	2	40
Design robustness	25						
Design life							
swivel cycles		5	125	3	75	3	75
pressure cycles		5	125	4	100	5	125
Pressure range							
internal		4	100	4	100	4	100
external		2	50	5	125	2	50
Temperature range		4	100	4	100	4	100
Installation	20						
Initial installatio/retrieval		2	40	3	60	4	80
Connection/disconnection		2	40	4	80	5	100
Operation	25						
Swivel resistance		1	25	4	100	5	125
Spool Length Short		1	25	4	100	5	125
Spool Length Long		3	75	5	125	5	125
Hub loads		2	50	4	100	5	125
Σ points			985		1165		1290

from master paper Halvard Bjørnsen, 2009

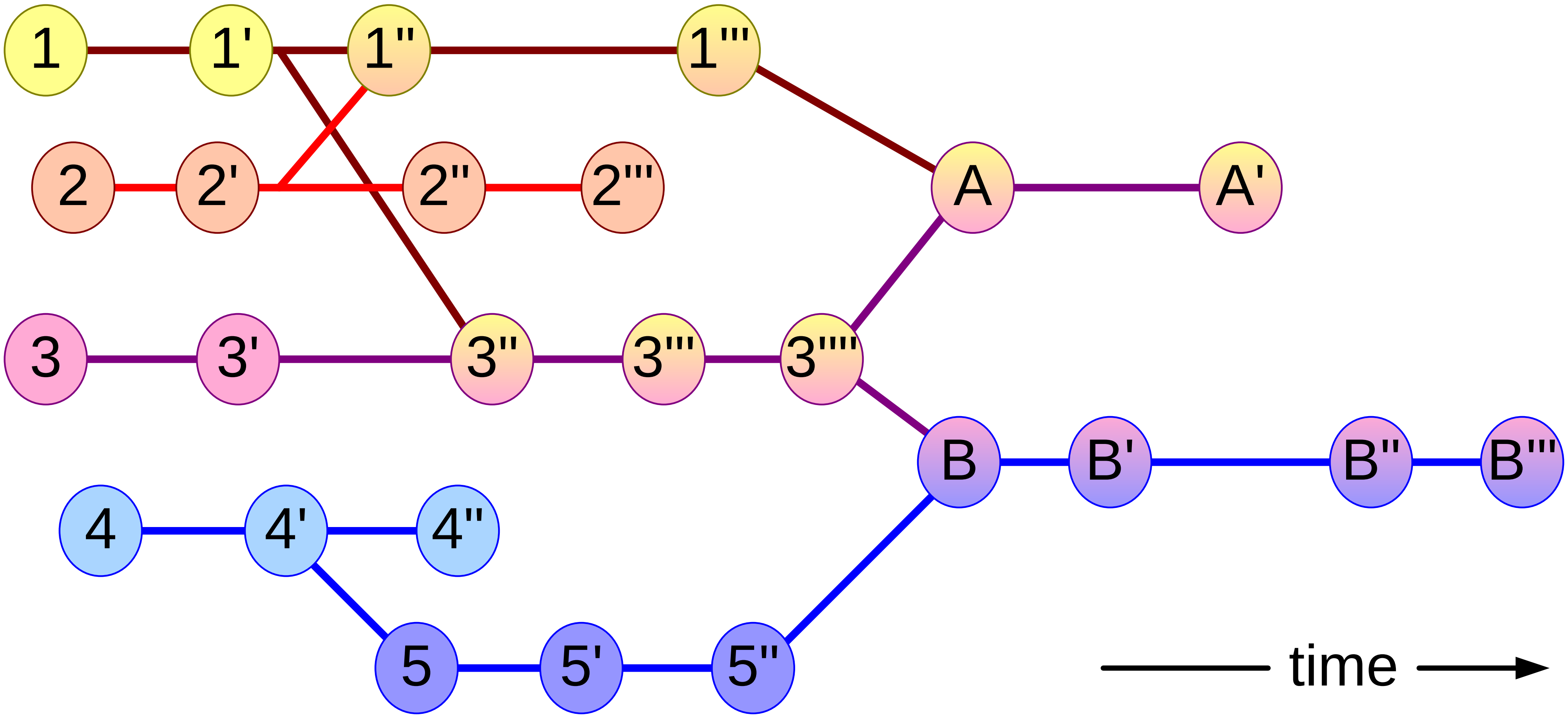
EDP-LRP connection



Evaluation Criteria	Score	Concepts 1	2	3	4
Time to connect					
Need for ROV		-	+	+	+
Design		-	+	+	+
Robustness					
Connector design		-	S	S	+
Number of parts		-	-	+	+
Handle roll-off		+	-	S	+
Influence other		+	S	-	S
Redundancy					
Design		+	-	-	S
Interchangeability		+	-	-	-
Cost					
HW cost		-	-	-	-
Manufacturing cost		S	S	-	S
Engineering cost		+	-	S	-
Service cost		-	+	+	+
Maturity		-	-	S	+
	Σ-	7	7	5	3
	ΣS	1	3	4	3
	Σ+	5	3	4	7
	Pos.	3	4	2	1

from master paper Dag Jostein Klever, 2009

Evolution of Design Options



Conclusions

Evolving multiple concepts increases insight and understanding (LEAN product development: set-based design, SE: Pugh matrix)

Articulation of criteria sharpens evaluation

The discussion about the Pugh matrix is more valuable than final bottomline summation

Delaying decisions may help to keep options (Lean Product Development: late decision making, finance: real options)

Exercise Concept Selection

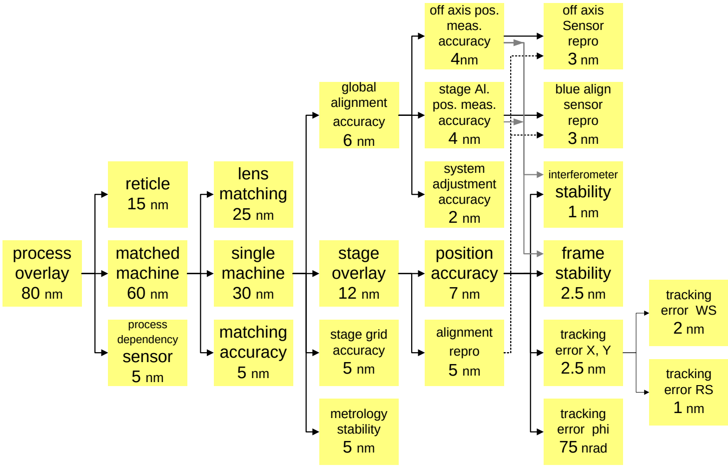
Make a **decision matrix** for one of the **concept selections**.

- define at least 3 concepts
- define 7 to 10 criteria for selection
- score the concepts against the criteria, for example using a scale from 1 to 5: 1 = very poor, 5 = very good
- recommend a concept with a rationale

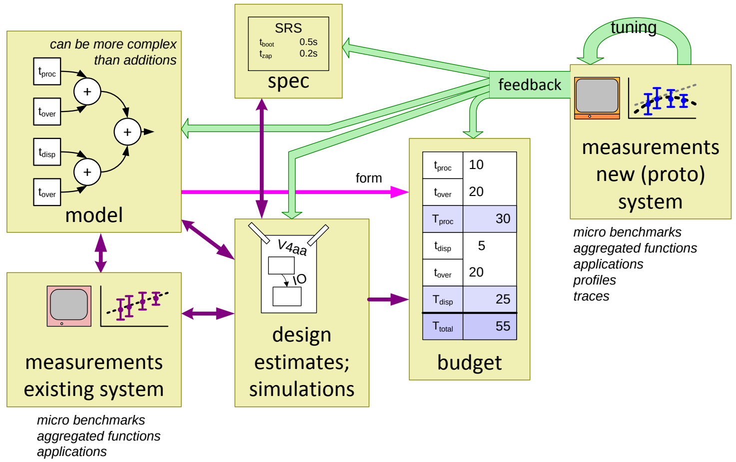
	concept 1	concept 2	concept 3
criterion 1	1	3	5
criterion n	4	4	2
			best, because ...

Budgeting

Budget: Decomposition of Contributions



plus Models, Measurements, Estimates



Tens of (Measurable) Numbers

memory budget in Mbytes	code	obj data	bulk data	total
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application SW total	13.4	12.6	35.0	61.0
UNIX Solaris 2.x				10.0
file cache				3.0
total				74.0

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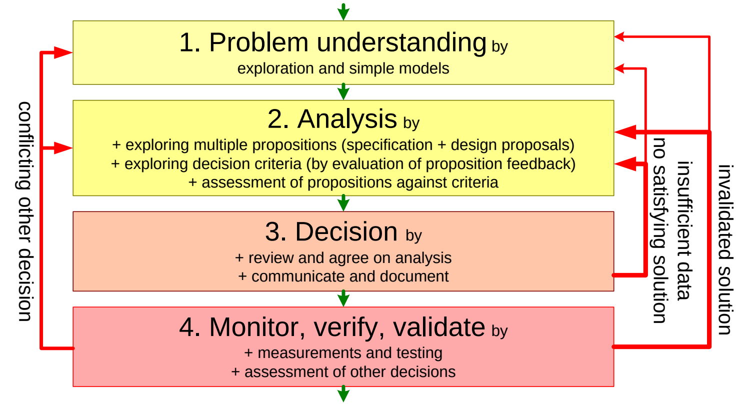
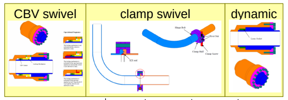
Concept Selection and Evolution

Understand Problem, Analyze, Decide, Monitor



Concept Selection: Pugh Matrix

Swivel concept selection



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Design life							
swivel cycles		5	125	3	75	3	75
pressure cycles		5	125	4	100	5	125
Pressure range							
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external		2	50	5	125	2	50
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Installation	20						
Initial installatio/retrieval		2	40	3	60	4	80
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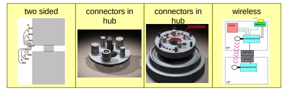

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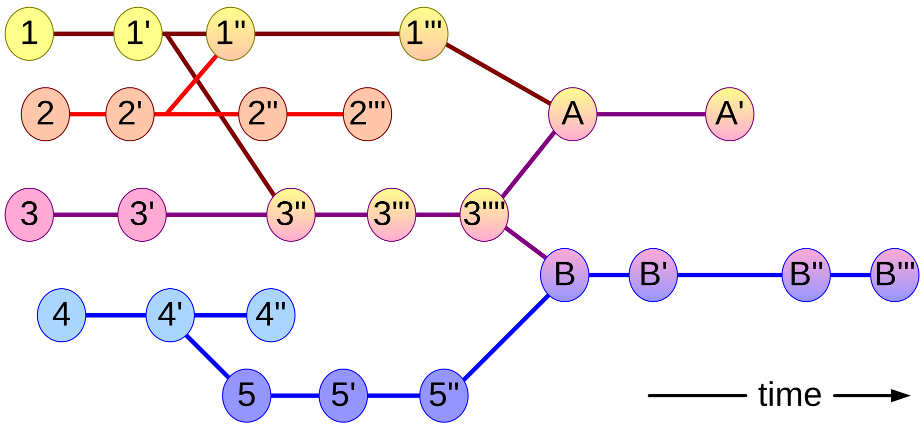
Design		-	+	+	+
Robustness					
Connector design		-	S	S	+
Number of parts		-	-	+	+
Handle roll-off		+	-	S	+
Influence other		+	S	-	S
Redundancy					
Design		+	-	-	S
Interchangeability		+	-	-	-
Cost					
HW cost		-	-	-	-
Manufacturing cost		S	S	-	S
Engineering cost		+	-	S	-
Service cost		-	+	+	+
Maturity		-	-	S	+
	Σ-	7	7	5	3
	ΣS	1	3	4	3
	Σ+	5	3	4	7
	Pos.	3	4	2	1

from master paper Dag Jostein Klever, 2009

Evolution of design Options



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Module 36, Architectural Reasoning Business and Life Cycle

by *Gerrit Muller* University of South-Eastern Norway-NISE
e-mail: gaudisite@gmail.com
www.gaudisite.nl

Abstract

This module provides methods and techniques to analyze the business and lifecycle context.

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Simplistic Financial Computations for System Architects.

by *Gerrit Muller* USN-SE
e-mail: `gaudisite@gmail.com`
`www.gaudisite.nl`

Abstract

This document explains how simple financial estimates can be made by system architects. These simplistic estimates are useful for an architect to perform sanity checks on proposals and to obtain understanding of the financial impact of proposals. Note that architects will never have full fledged financial controller know how and skills. These estimates are zero order models, but real business decisions will have to be founded on more substantial financial proposals.

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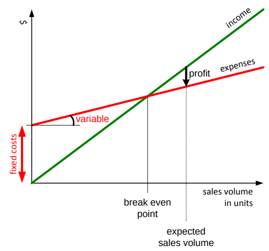
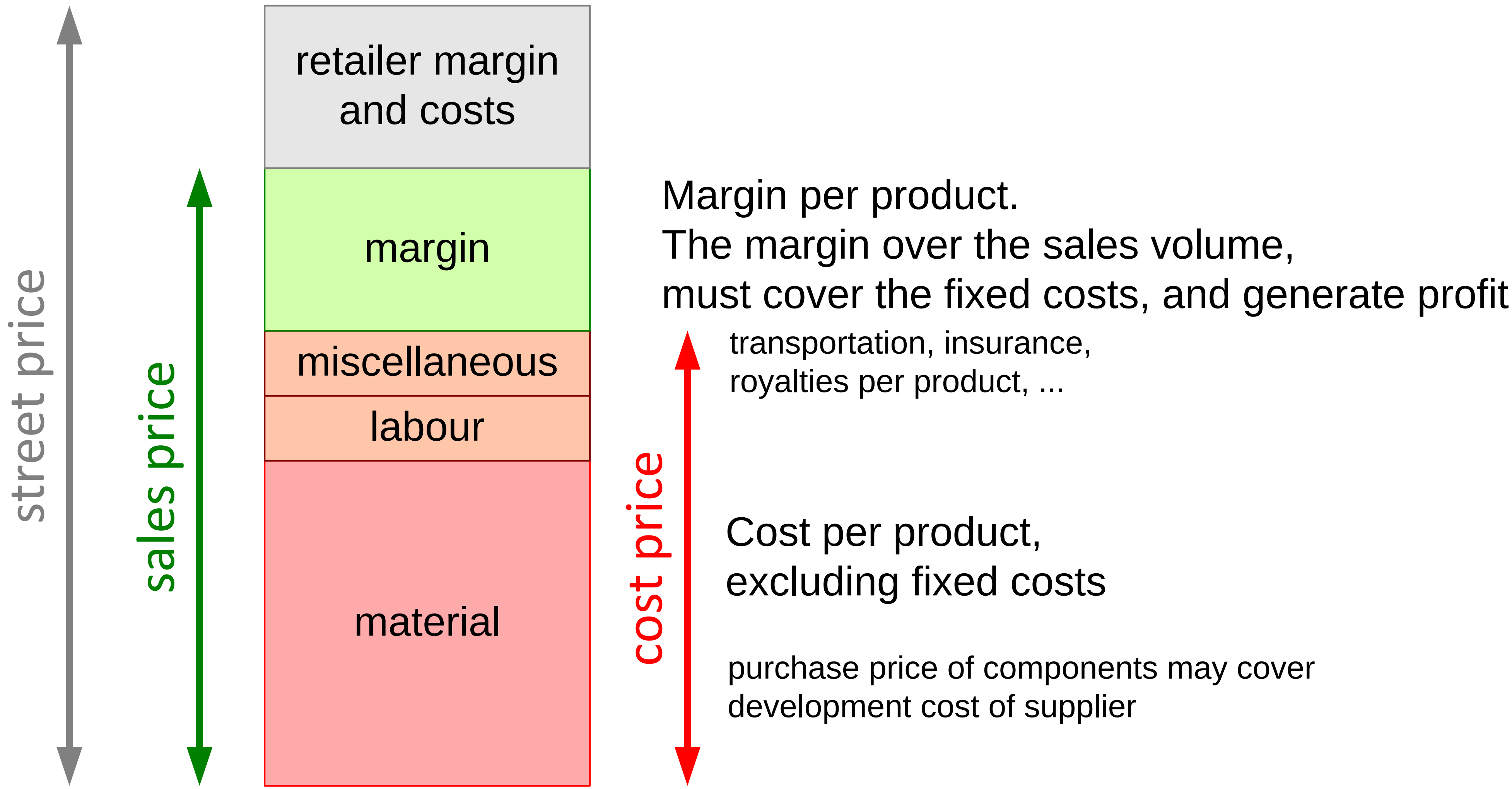
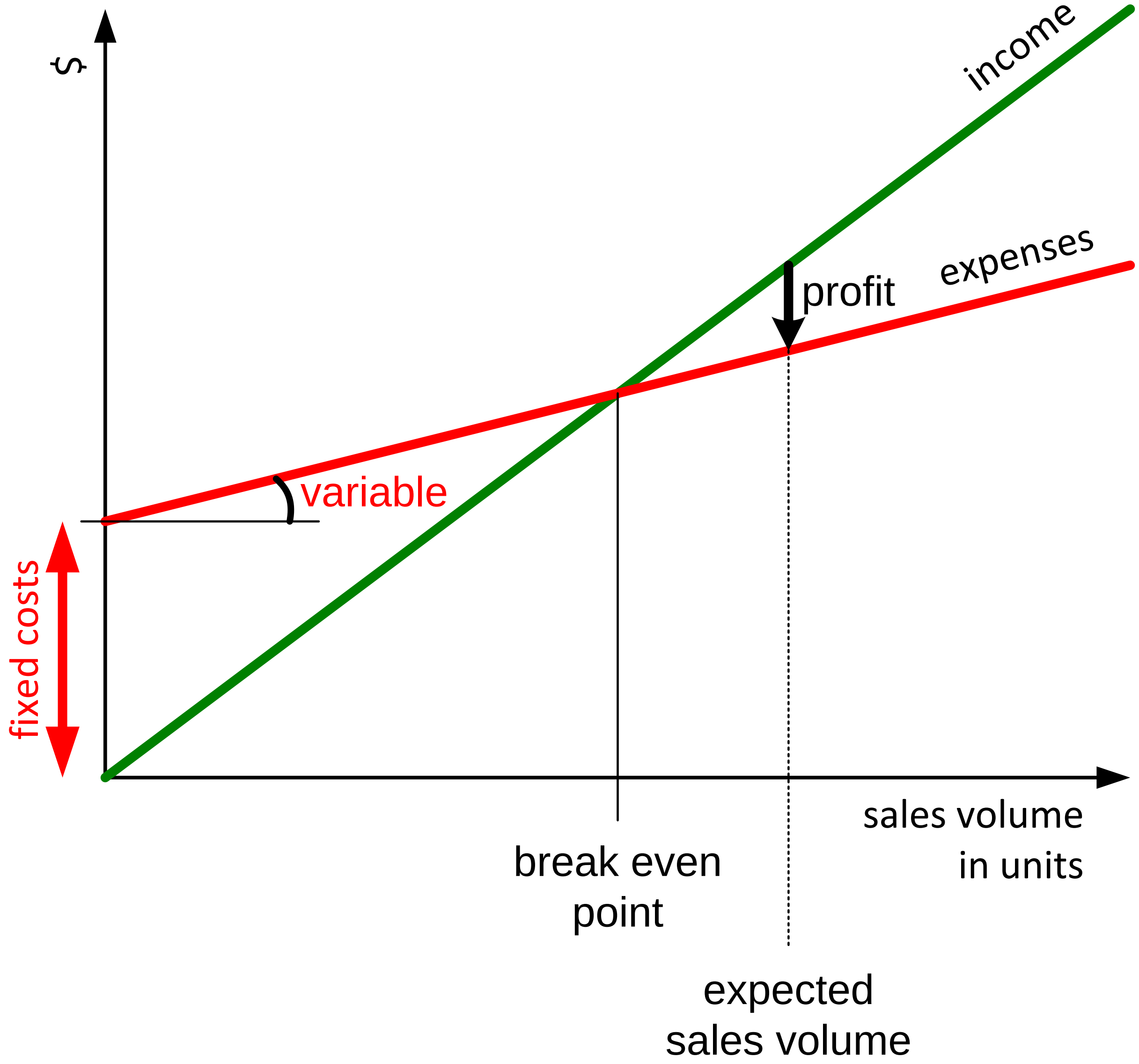


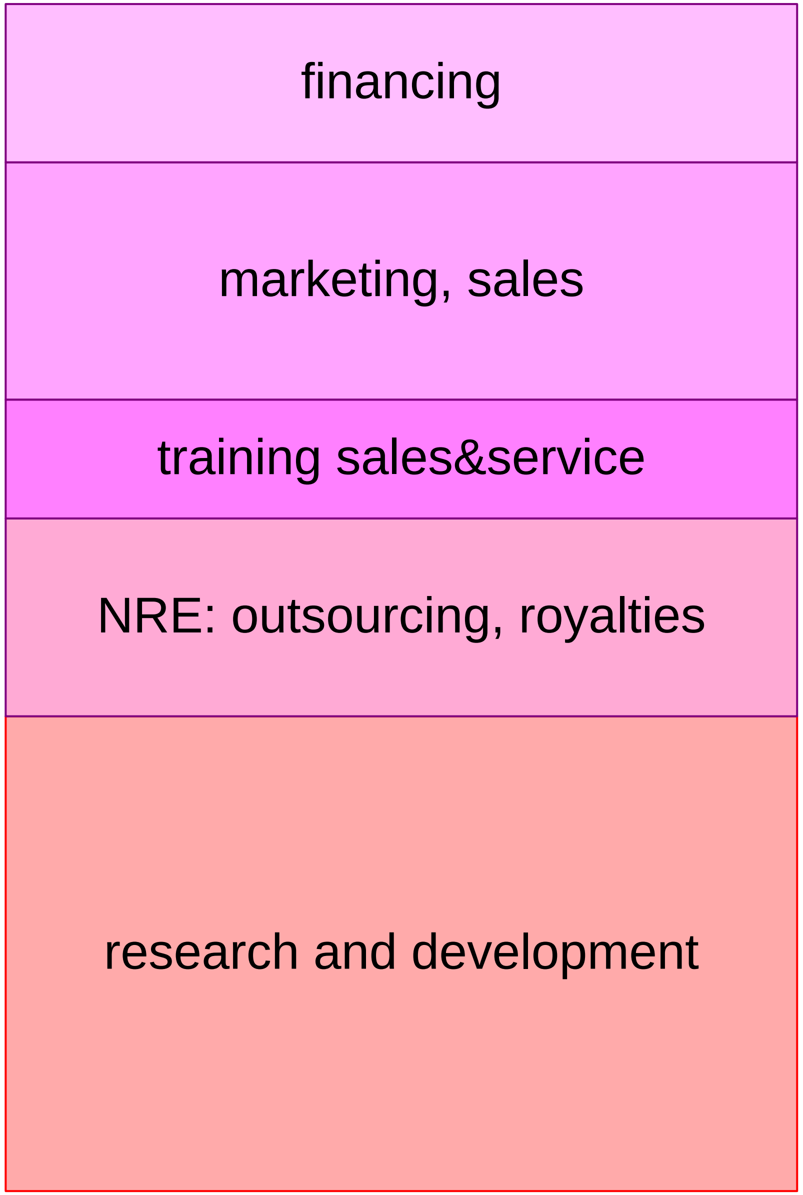
Product Margin = Sales Price - Cost



Profit as function of sales volume



Investments, more than R&D



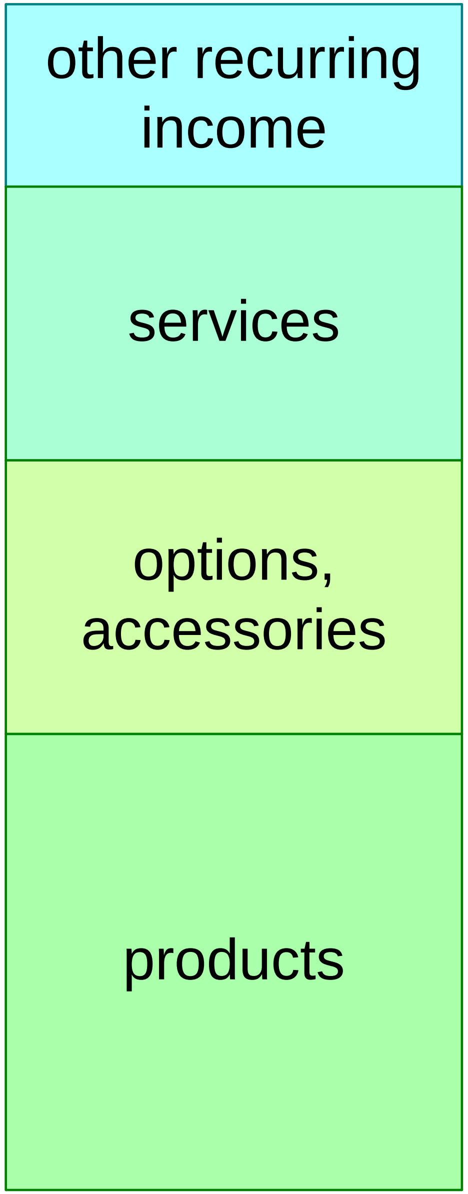
business dependent:
pharmaceutics industry
sales cost >> R&D cost

strategic choice:
NRE or per product

including:
- staff, training, tools, housing
- materials, prototypes
- overhead
- certification

often a standard staffing rate is used
that covers most costs above:
R&D investment = Effort * rate

Income, more than product sales only



$$\sum_{\text{services}} \text{income}_{\text{service}}$$

$$\sum_{\text{options}} \text{sales price}_{\text{option}} * \text{volume}_{\text{option}}$$

$$\text{sales price}_{\text{product}} * \text{volume}_{\text{product}}$$

license fees
pay per movie

content, portal
updates
maintenance

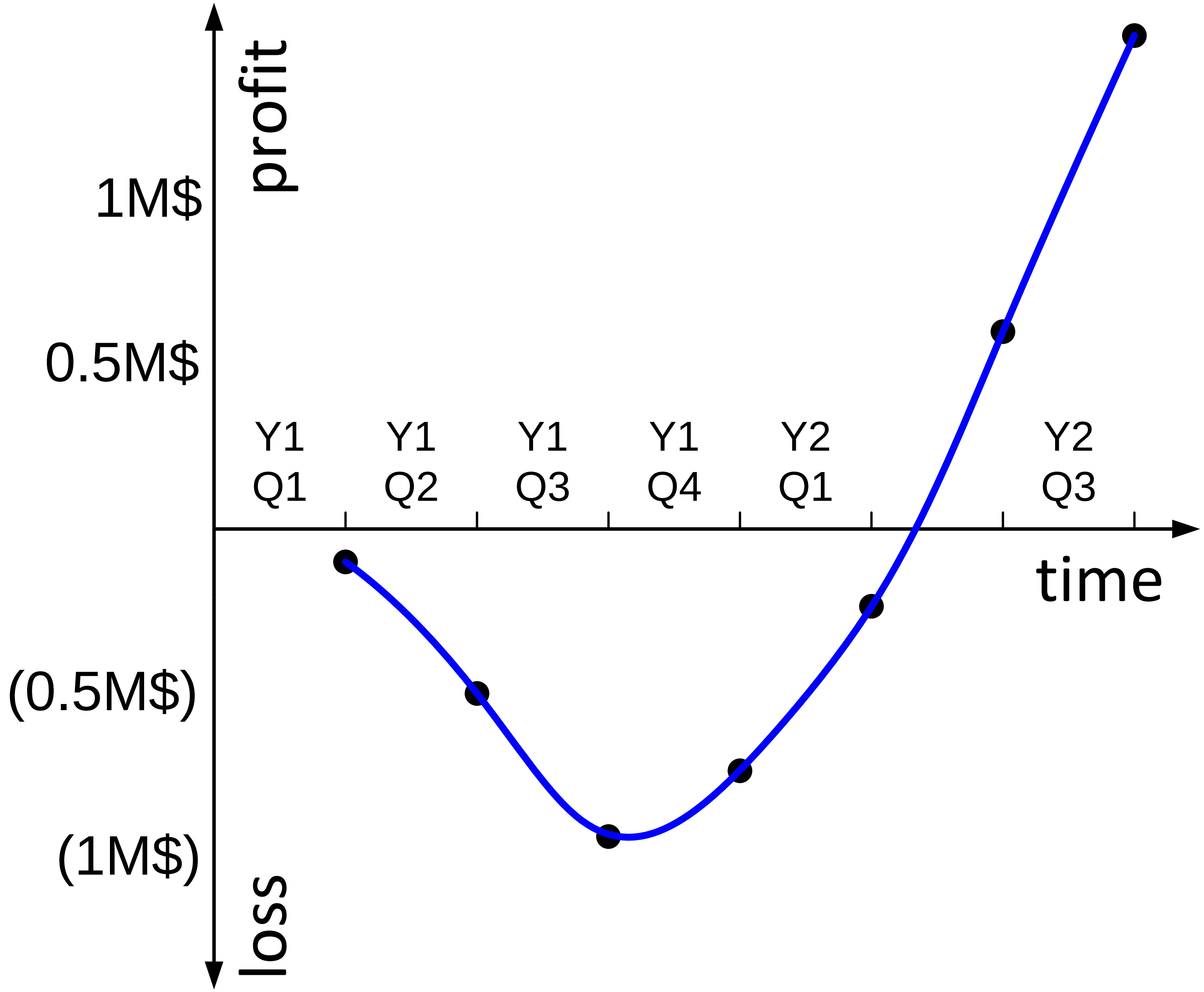
The Time Dimension

	Y1 Q1	Y1 Q2	Y1 Q3	Y1 Q4	Y2 Q1	Y2 Q2	Y2 Q3
investments	100k$	400k$	500k$	100k$	100k$	60k$	20k$
sales volume (units)	-	-	2	10	20	30	30
material & labour costs	-	-	40k$	200k$	400k$	600k$	600k$
income	-	-	100k$	500k$	1000k$	1500k$	1500k$
quarter profit (loss)	(100k$)	(400k$)	(440k$)	200k$	500k$	840k$	880k$
cumulative profit	(100k$)	(500k$)	(940k$)	(740k$)	(240k$)	600k$	1480k$

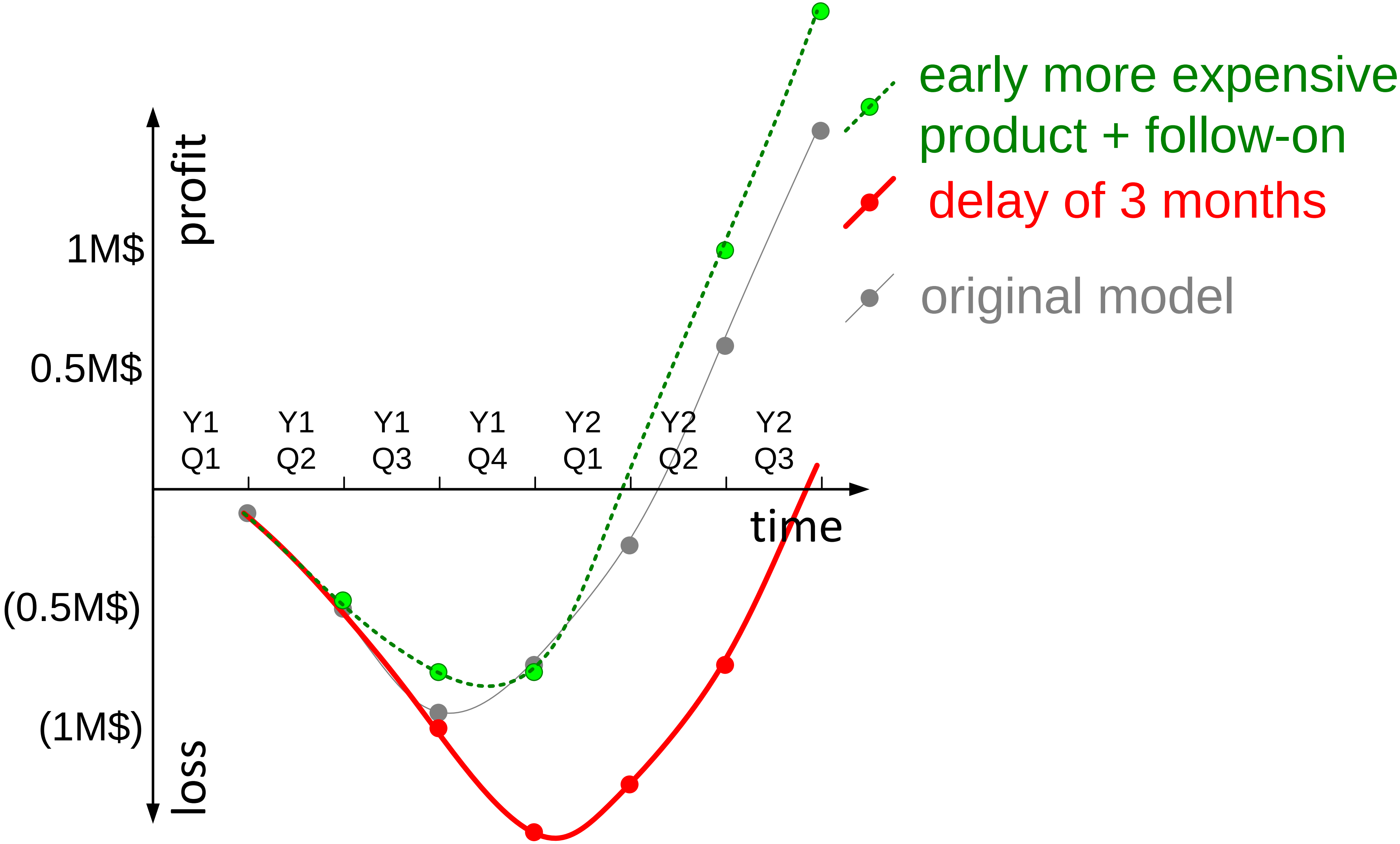
cost price / unit = 20k$
sales price / unit = 50k$

variable cost = sales volume * cost price / unit
income = sales volume * sales price / unit
quarter profit = income - (investments + variable costs)

The "Hockey" Stick

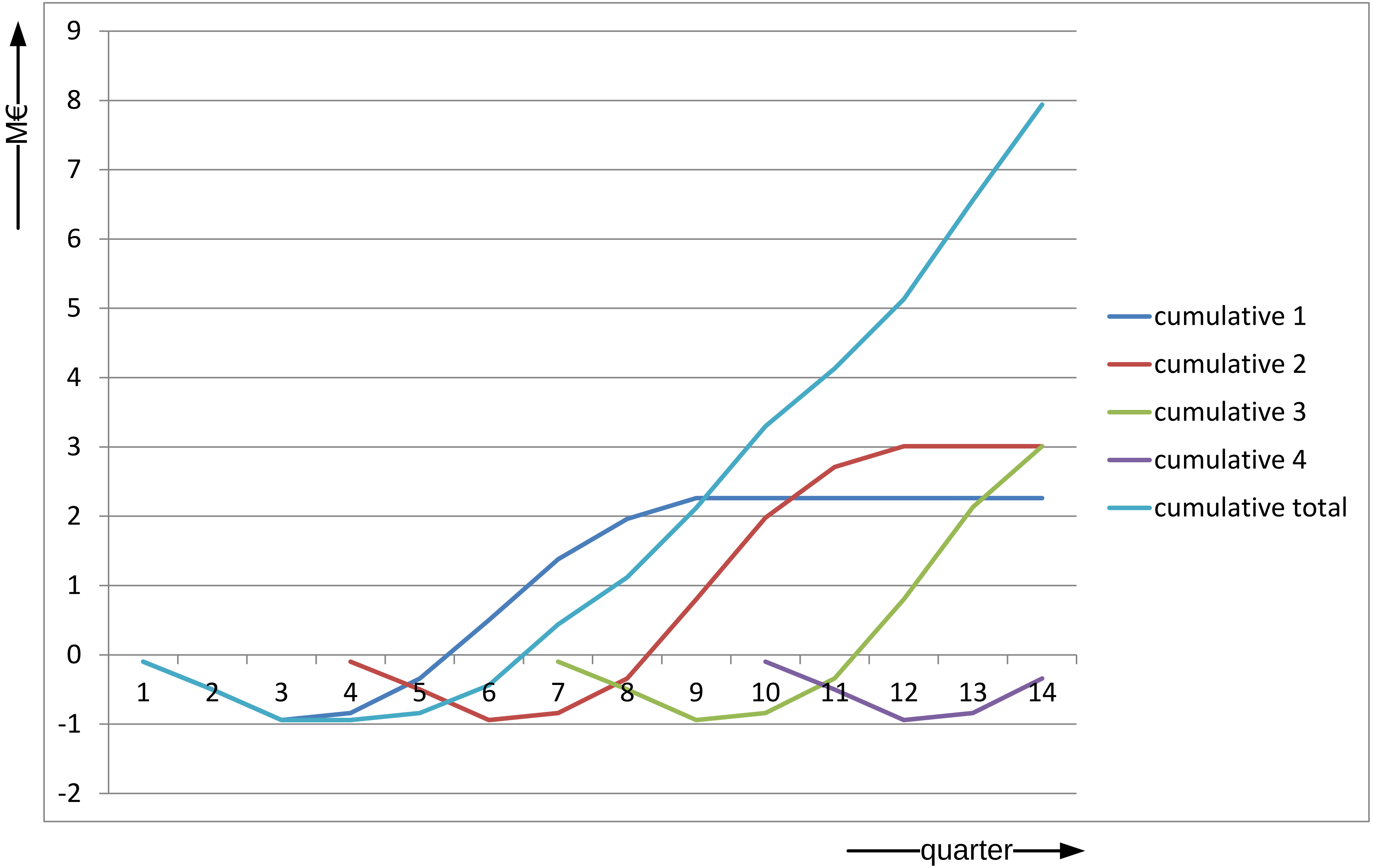


What if ...?



profit
loss
1M$
0.5M$
(0.5M$)
(1M$)
Y1 Q1
Y1 Q2
Y1 Q3
Y1 Q4
Y2 Q1
Y2 Q2
Y2 Q3
time
early more expensive product + follow-on
delay of 3 months
original model

Stacking Multiple Developments



Fashionable financial yardsticks

Return On Investments (ROI)

Net Present Value

Return On Net Assets (RONA) leasing reduces assets, improves RONA

turnover / fte outsourcing reduces headcount, improves this ratio

market ranking (share, growth) "only numbers 1, 2 and 3 will be profitable"

R&D investment / sales in high tech segments 10% or more

cash-flow fast growing companies combine profits with negative cash-flow, risk of bankruptcy

Exercise Business Plan

Make a **business plan** for the mid to long-term future.

- determine business model
- determine investments, sales volume, sales price, and costs
- estimate the cash flow and accumulated profit
- include at least 3 releases or generations of systems

Modeling and Analysis: Life Cycle Models

by *Gerrit Muller* University of South-Eastern Norway-NISE
e-mail: gaudisite@gmail.com
www.gaudisite.nl

Abstract

Products and enterprises evolve over time. This presentation explores the impact of these changes on the system and on the business by making (small and simple) models of life cycle aspects.

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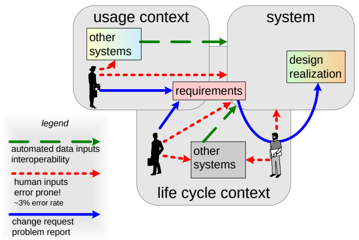
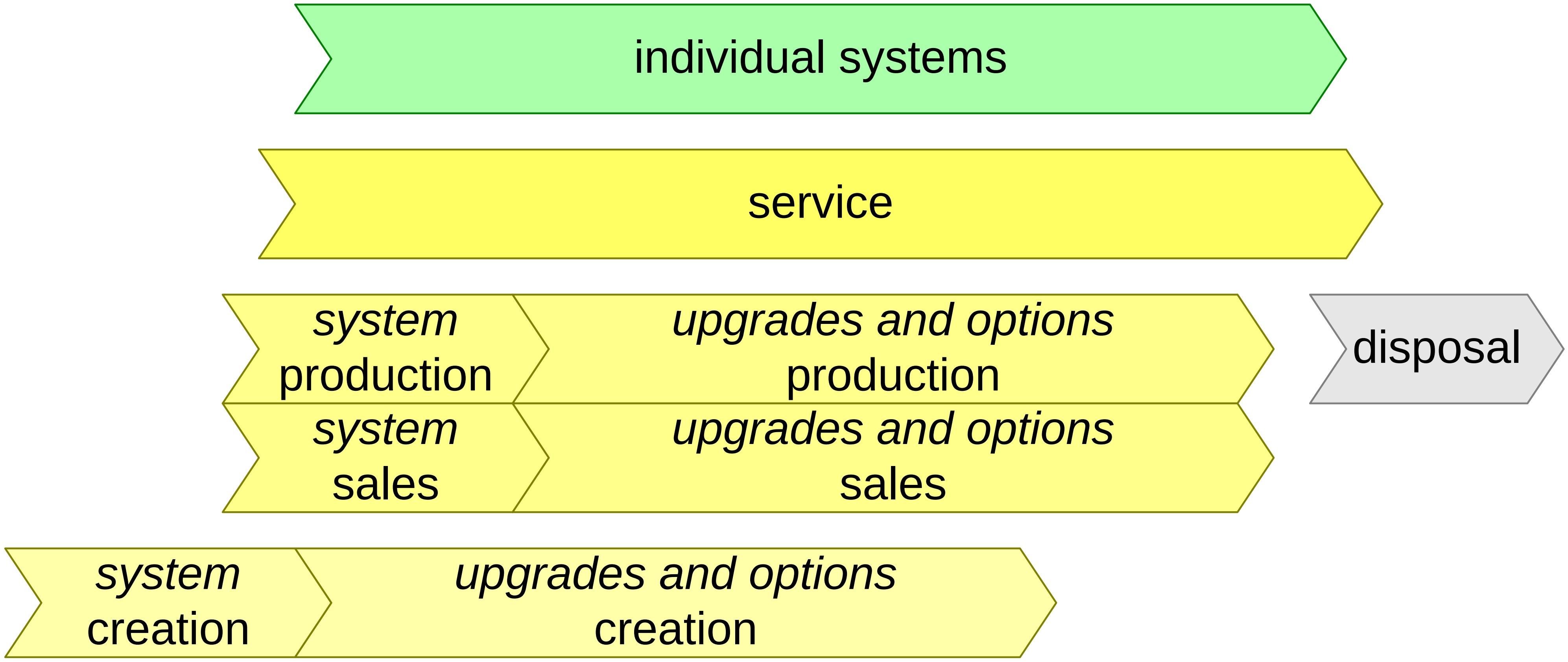
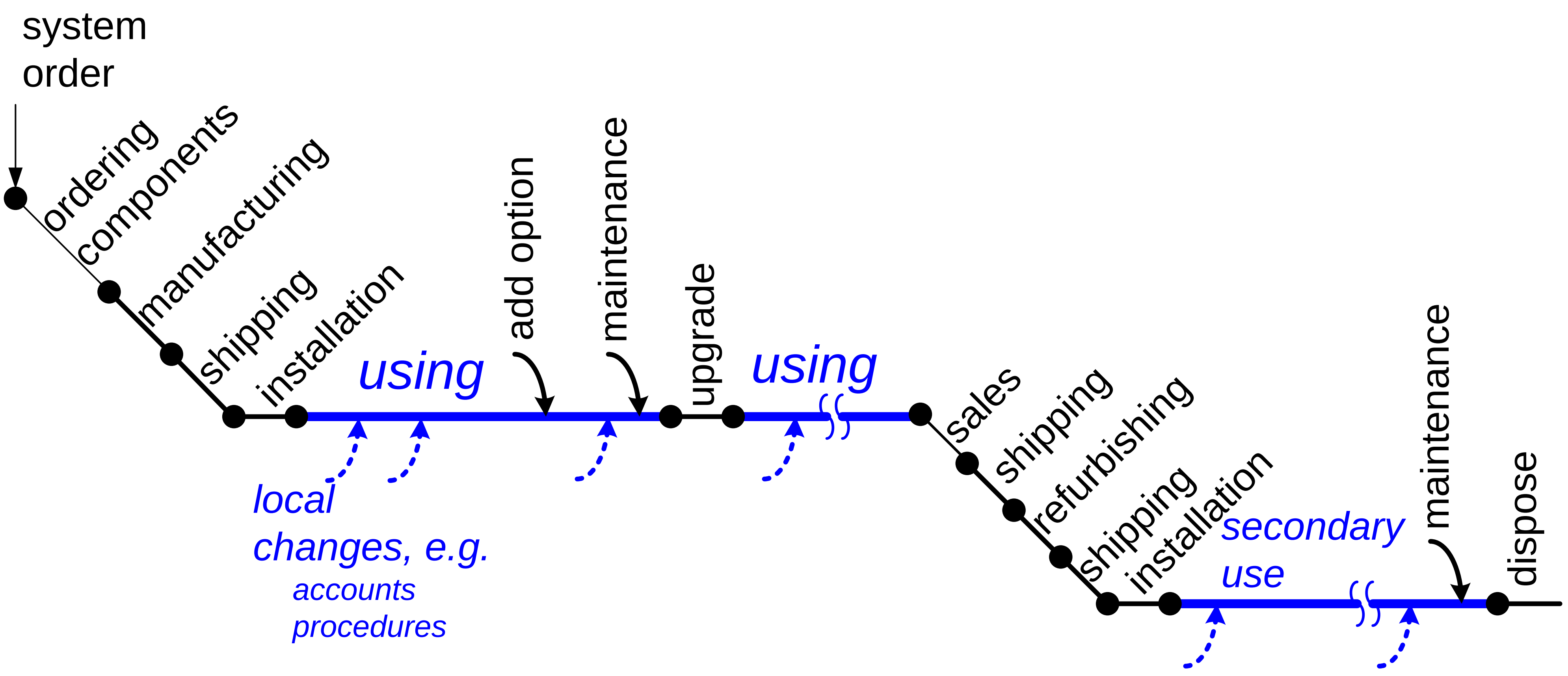


Product Related Life Cycles



System Life Cycle



Approach to Life Cycle Modeling

Identify potential life cycle changes and sources	
Characterize time aspect of changes	how often how fast
Determine required effort	amount type
Determine impact of change on system and context	performance reliability
Analyse risks	business

see reasoning

What May Change During the Life Cycle?

business volume

product mix

product portfolio

product attributes (e.g. price)

customers

personnel

suppliers

application, business processes

et cetera

www.homes4sale.com

www.apple.com/itunes/

www.amazon.com

www.ebay.com

www.shell.com

www.stevens.edu

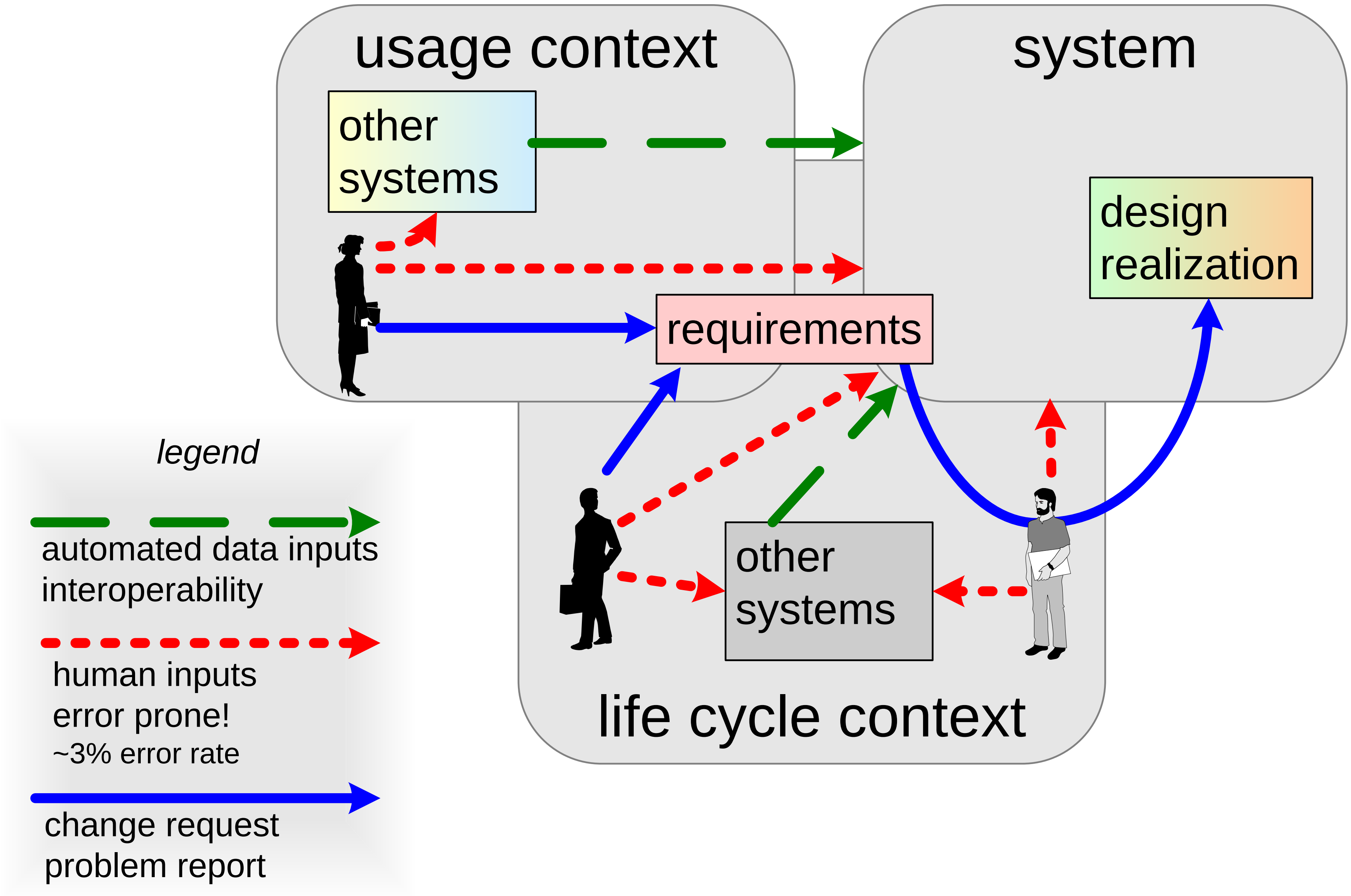
www.nokia.com

stock market

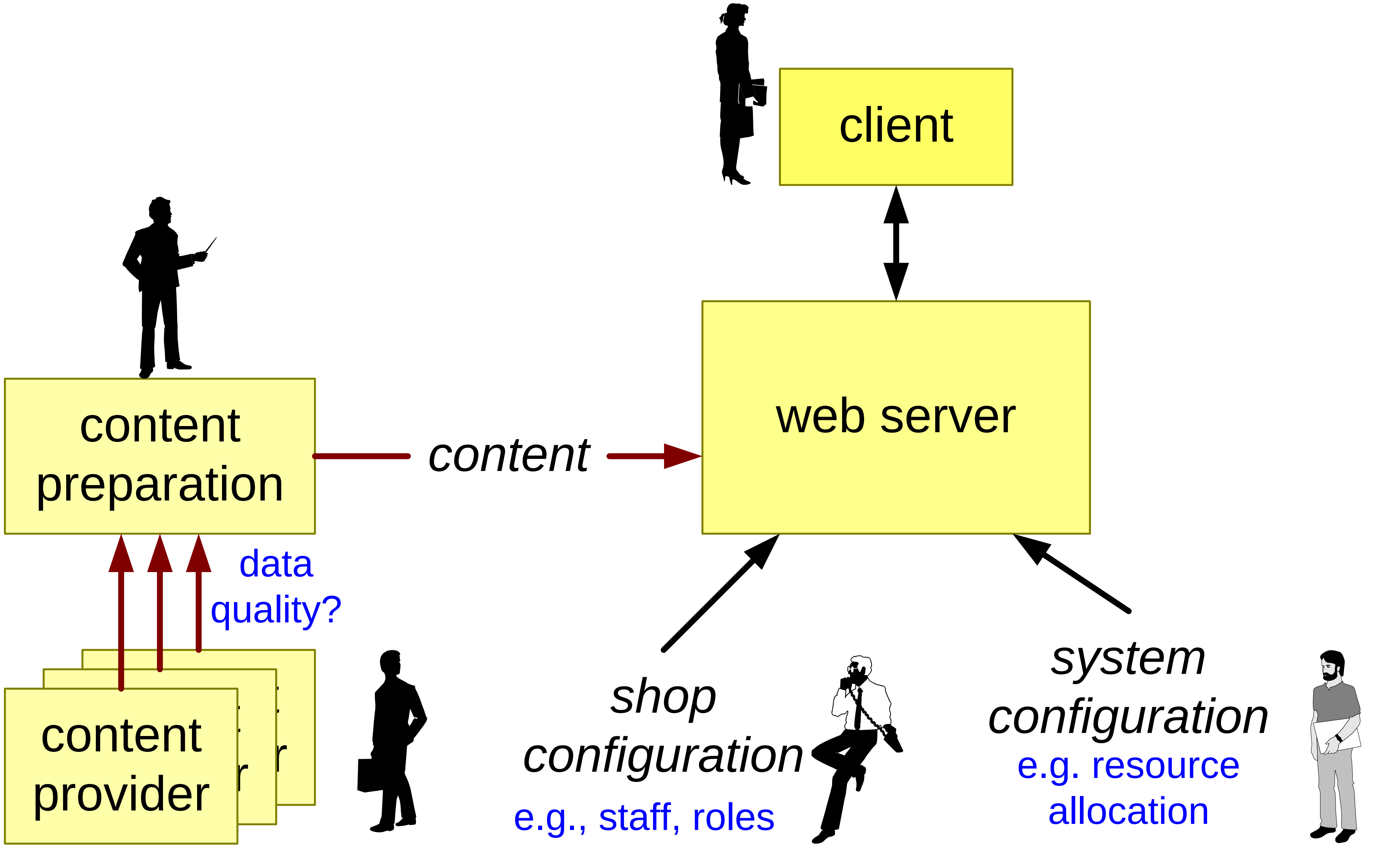
insurance company

local Dutch cheese shop

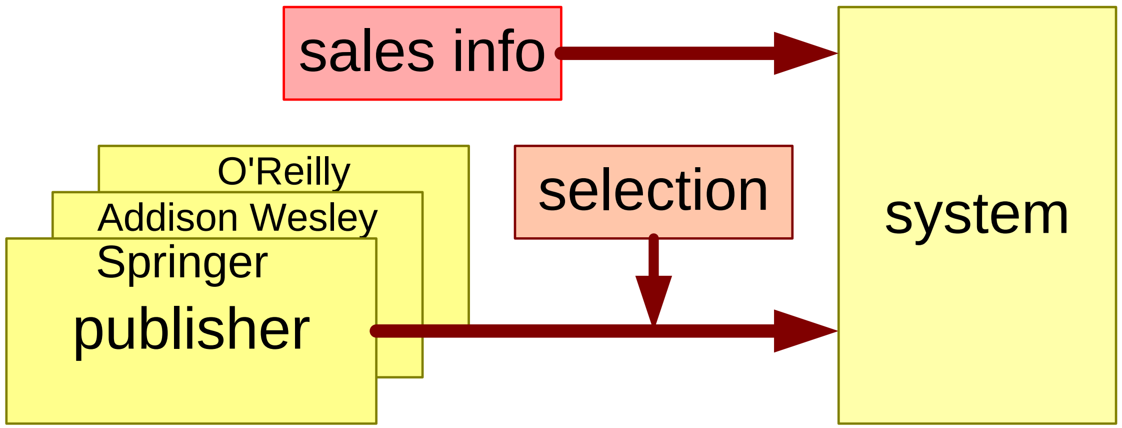
Simple Model of Data Sources of Changes



Data Sources of Web Server



Example Product Portfolio Change Books

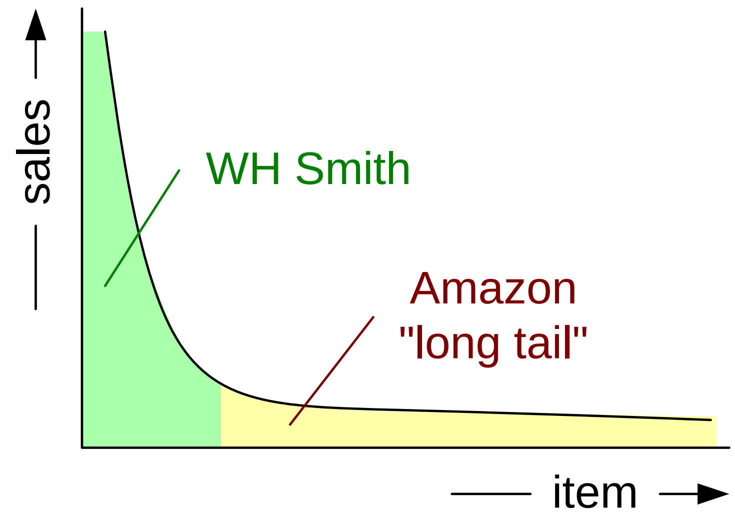


product portfolio characteristics

selection depends on business

life cycle changes determined by business characteristics

source: http://en.wikipedia.org/wiki/Long_tail



new books per year

UK (1)	206k (2005)	107k (1996)
USA(2)	172k (2005)	68k (1996)
China(3)		101k (1994)
India(21)		12k (1996)

source: http://en.wikipedia.org/wiki/Books_published_per_country_per_year

Example Customer Change

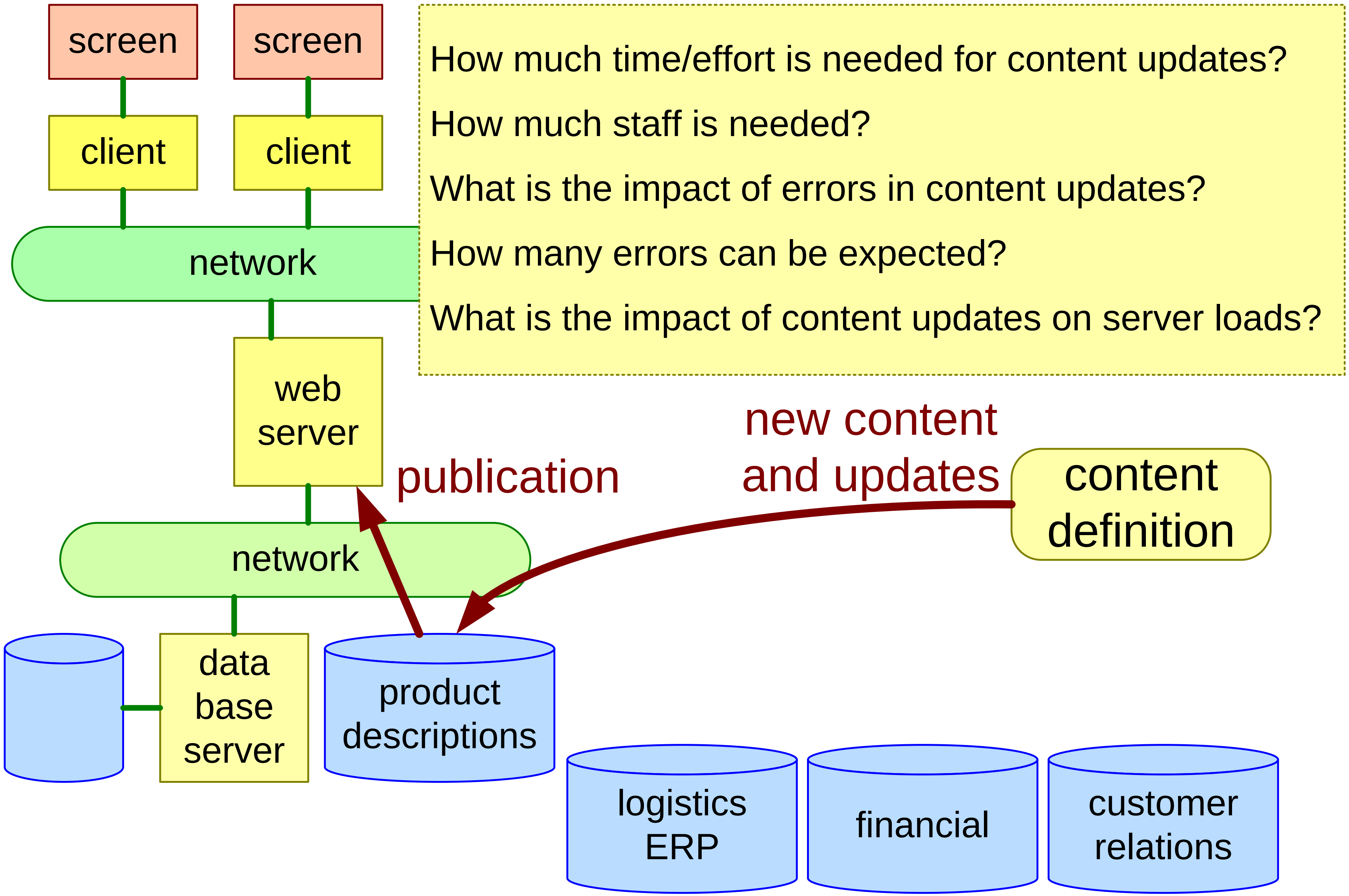
internet: broadband penetration

	Q1 '04	Q2 '04	growth in Q2 '04
Asia Pacific total	48M	54M	12.8%
China	15M	19M	26.1%
India	87k	189k	116.8%

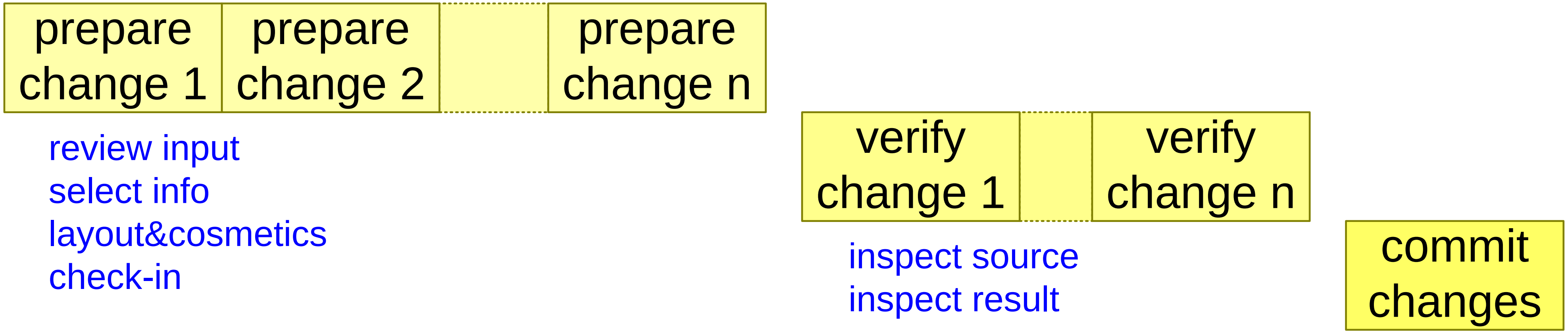
http://www.apira.org/download/world_broadband_statistics_q2_2004.pdf

What is the expected growth of # customers?
What is the impact on system and infrastructure?
What is the impact on CRM (Customer Relation Management)?
What is the impact on customer, sales support staff?

Web Shop Content Update



Web Shop Content Change Effort



$$effort_{changes} = n_{changes} * (t_{prepare} + t_{verify}) + t_{commit}$$

$$\#fte = effort_{changes} / \text{hours per day}$$

with $t_{prepare}$ = 4 min

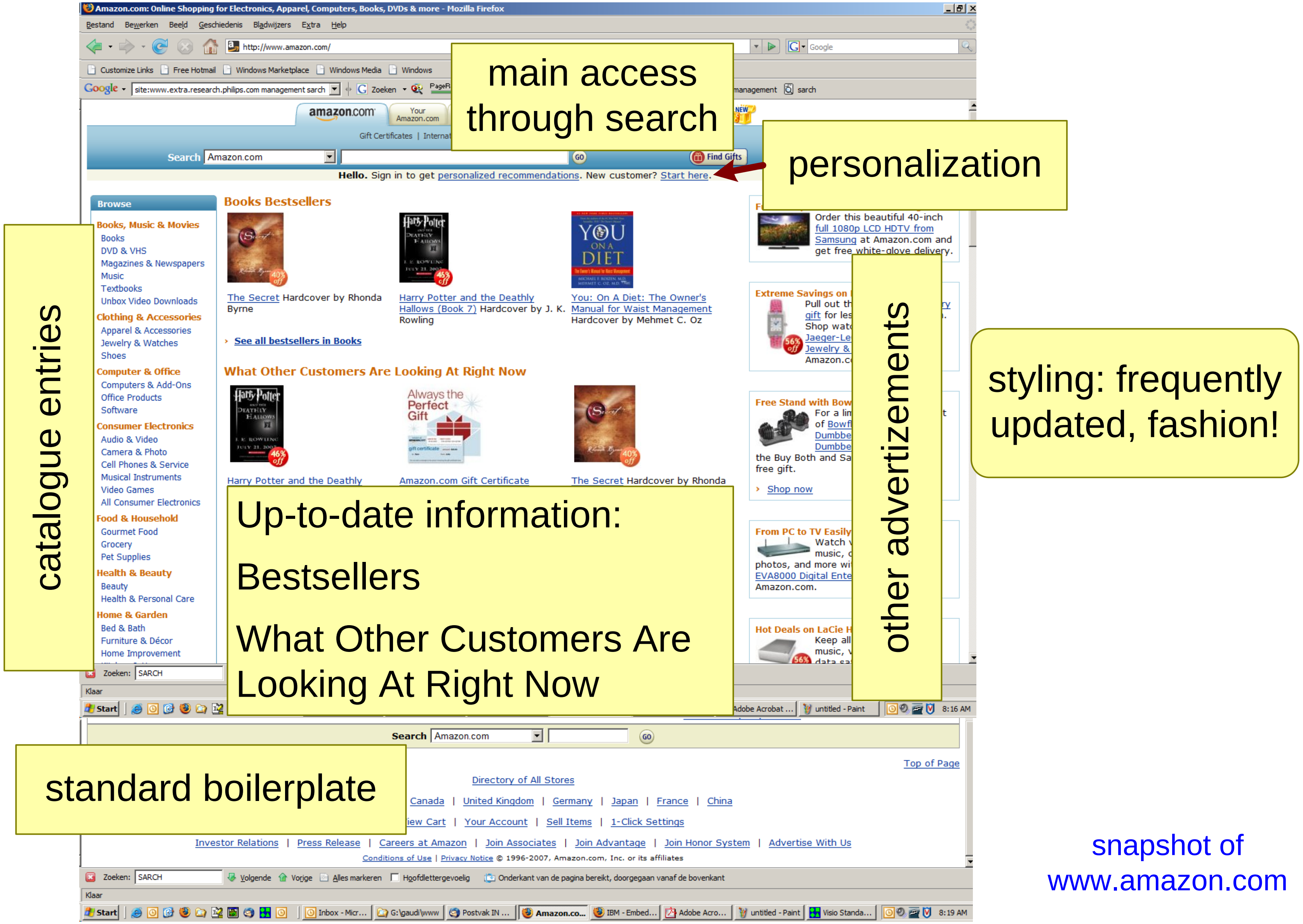
t_{verify} = 2 min

t_{commit} = 1 min

hours per day = 8 hours

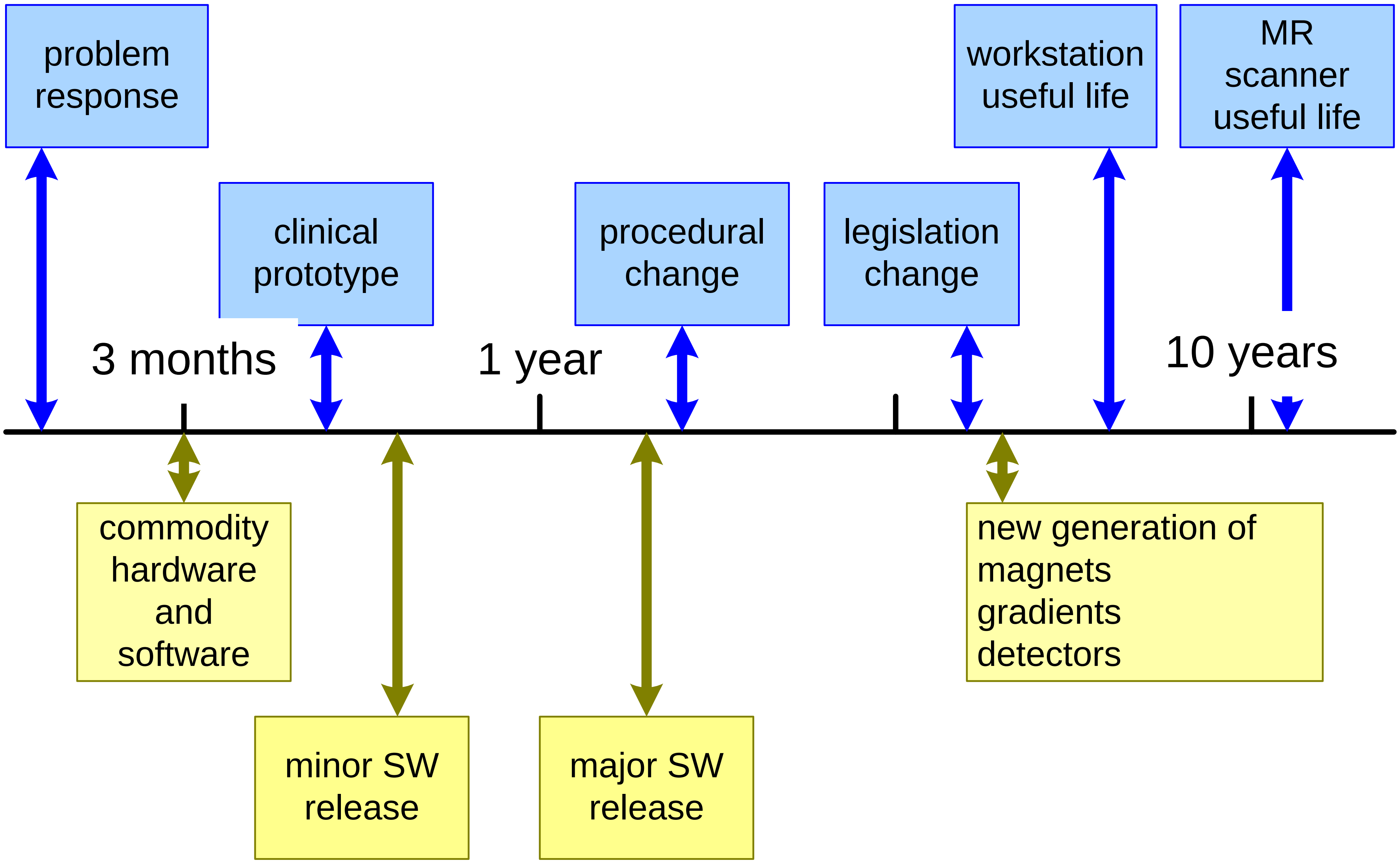
$n_{changes}$ per day	10	100	1000
$effort_{changes}$	1 uur	10 uur	100 uur
#fte	0.1	1	12

Example of Client Level Changes

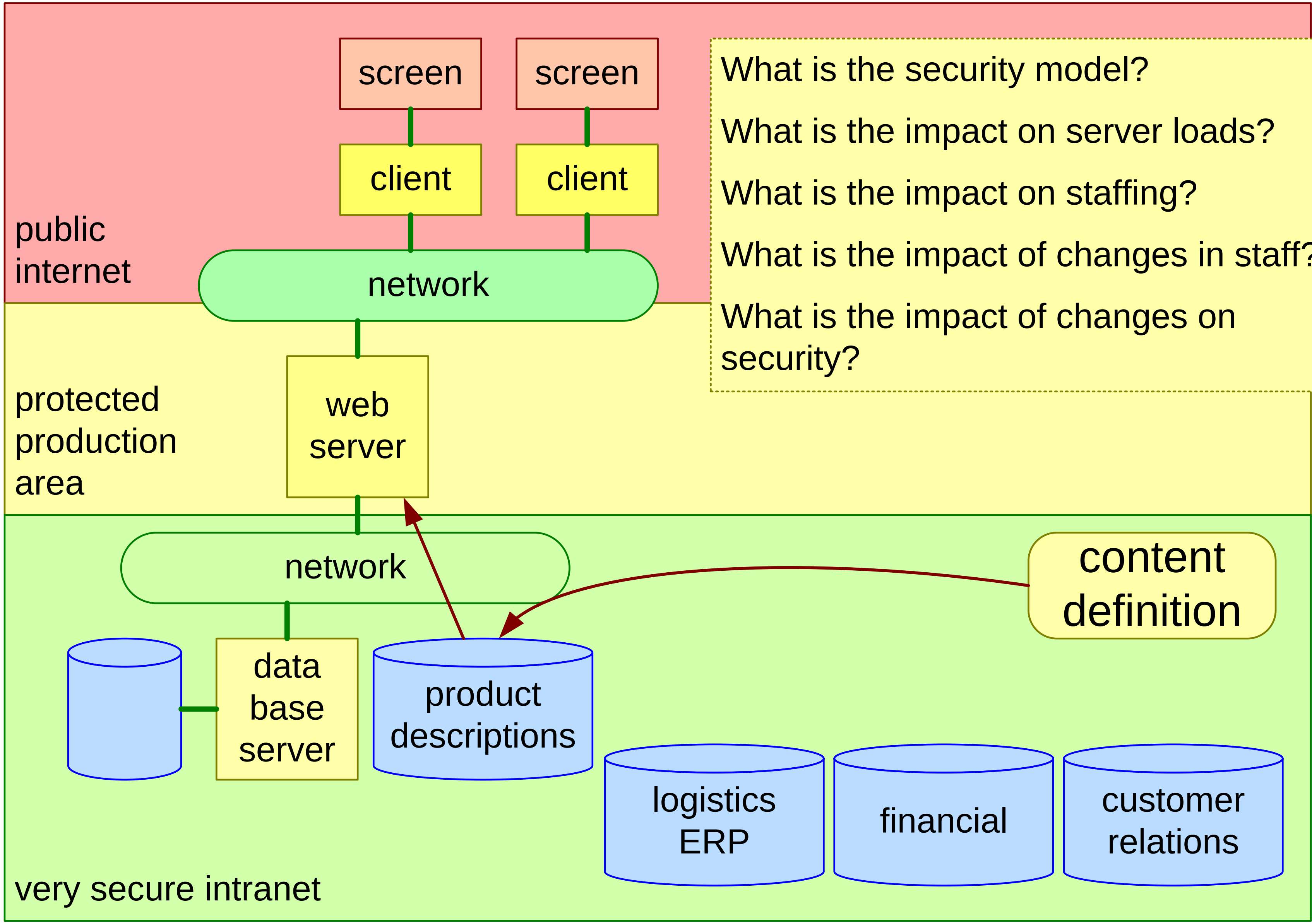


snapshot of www.amazon.com

Example of Time Scale Model for Changes



Web Shop Security and Changes



What is the security model?

What is the impact on server loads?

What is the impact on staffing?

What is the impact of changes in staff?

What is the impact of changes on security?

Web Shop Reliability and Changes

new faults = average fault density * #changes

$$\#errors = \sum_{faults} f(\text{severity}, \text{hit probability}, \text{detection probability})$$

	severity	hit probability	detection probability
Jansen iso *Janssen*	low	high	low
operator iso *sales repr*	high	high	medium

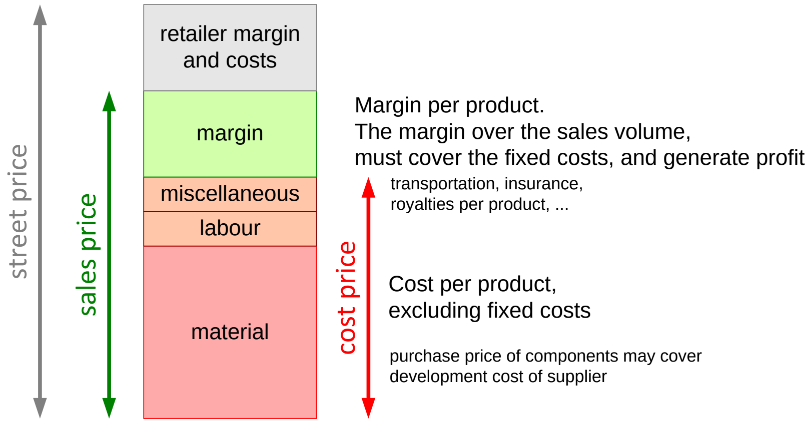
Exercise Life Cycle

Analyze the **evolution** during the **lifecycle**.

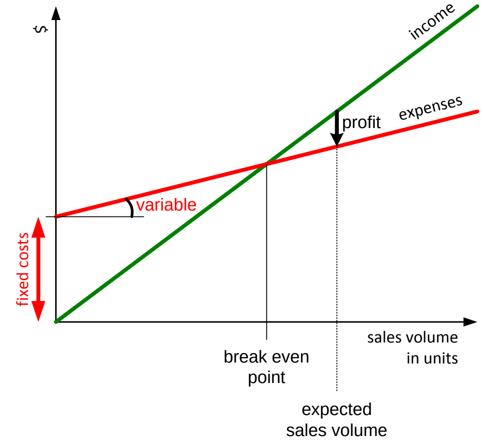
- identify sources of change in customer context, life cycle context, and technology
- make a list of changes
- determine per change the expected rate of change and the required response time to the change
- optional: determine effort, impact, and risks per change

Simplistic Financial Computations

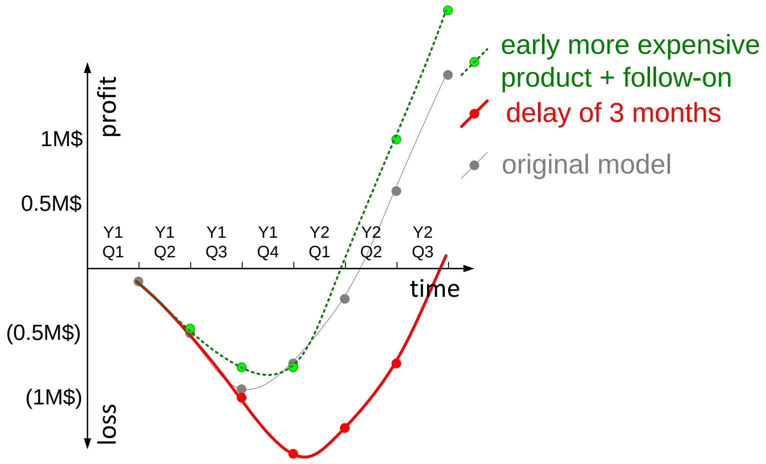
Product Margin = Sales Price - Cost



Profit as function of sales volume



Hockey stick and scenarios



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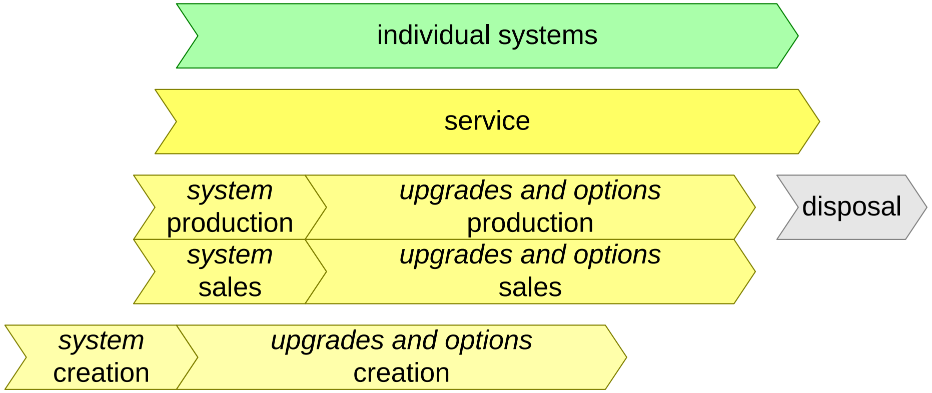
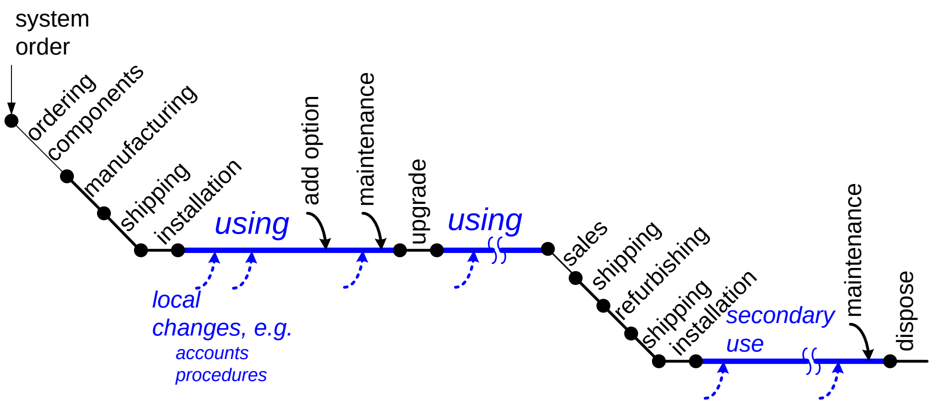
Life Cycle

Multiple Life Cycles



System Life Cycle

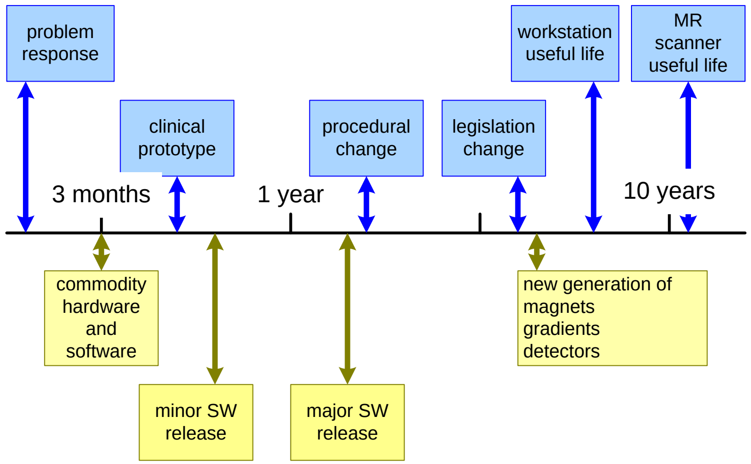


Analyze Frequency, Response Need, and Impact

Identify potential life cycle changes and sources	
Characterize time aspect of changes	how often how fast
Determine required effort	amount type
Determine impact of change on system and context	performance reliability
Analyse risks	business

see reasoning

Logarithmic Axis of Change Frequency



Module 37, Architectural Reasoning Threads and Integration

by *Gerrit Muller* University of South-Eastern Norway-NISE
e-mail: gaudisite@gmail.com
www.gaudisite.nl

Abstract

This module provides methods and techniques to integrate insights across views. Lines and Threads of reasoning form the main framework.

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Qualities as Integrating Needles

by *Gerrit Muller* University of South-Eastern Norway-NISE
e-mail: gaudisite@gmail.com
www.gaudisite.nl

Abstract

Many stakeholder concerns can be specified in terms of qualities. These qualities can be viewed from all 5 “CAFCR” viewpoints. In this way qualities can be used to relate the views to each other.
The meaning of qualities for the different views is described. A checklist of qualities is provided as a means for architecting. All qualities in the checklist are described briefly.

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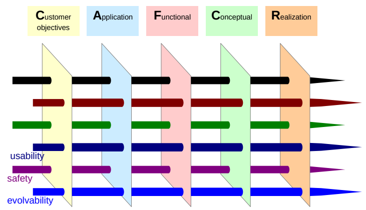
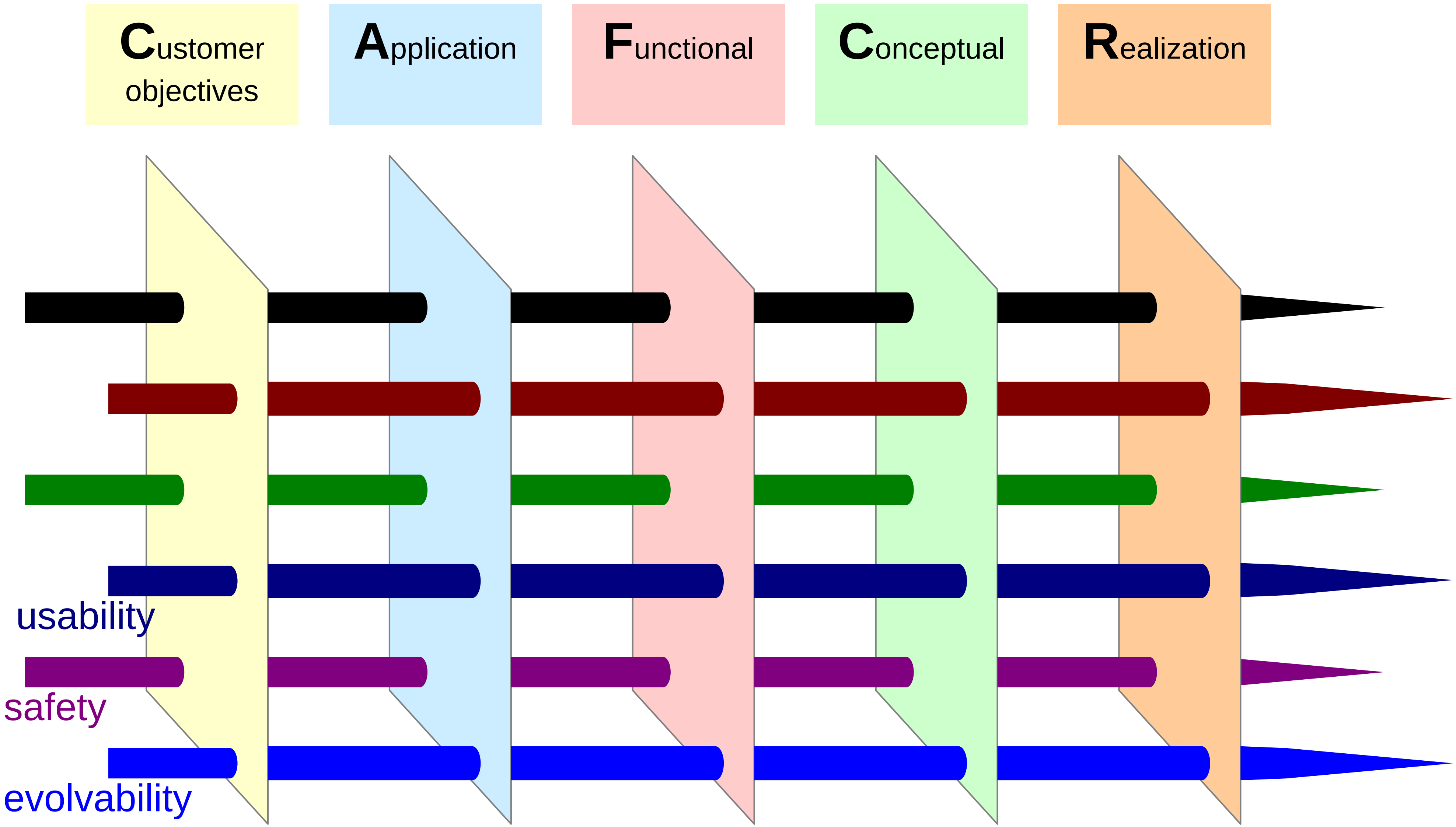
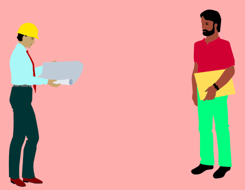


Quality needles as generic integrating concepts



Security as example through all views

Customer objectives	**A**pplication	**F**unctional	**C**onceptual	**R**ealization
sensitive information  trusted	selection classification people information authentication badges passwords locks / walls guards administrators	functions for administration authentication intrusion detection logging quantification	cryptography firewall security zones authentication registry logging	*specific* algorithms interfaces libraries servers storage protocols
 not trusted	social contacts open passwords blackmail burglary fraud unworkable procedures	missing functionality wrong quantification	holes between concepts	bugs buffer overflow non encrypted storage poor exception handling

desired characteristics, specifications & mechanisms

threats

Quality Checklist

usable
- usability
- attractiveness
- responsiveness
- image quality
- wearability
- storability
- transportability

dependable
- safety
- security
- reliability
- robustness
- integrity
- availability

effective
- throughput or productivity

interoperable
- connectivity
- 3rd party extendible

liable
- liability
- testability
- traceability
- standards compliance

efficient
- resource utilization
- cost of ownership

consistent
- reproducibility
- predictability

serviceable
- serviceability
- configurability
- installability

future proof
- evolvability
- portability
- upgradeability
- extendibility
- maintainability

logistics friendly
- manufacturability
- logistics flexibility
- lead time

ecological
- ecological footprint
- contamination
- noise
- disposability

down to earth attributes
- cost price
- power consumption
- consumption rate (water, air, chemicals, et cetera)
- size, weight
- accuracy

Exercise Line of Reasoning

Make a **line of reasoning** for one of the dominant qualities.

- in the CA views; determine what customers do to achieve their goal
- in the F view determine the specification of your system supporting this quality
- in the CR views determine the relevant concepts and technologies
- Take the reverse viewpoints as well: what threatens this quality?

Threads of Reasoning

by *Gerrit Muller* University of South-Eastern Norway-NISE
e-mail: gaudisite@gmail.com
www.gaudisite.nl

Abstract

A method of reasoning is described, which addresses cross-cutting issues. The basis is fast iteration in the problem and solution space.
A thread of reasoning is a set of highly relevant related issues, which are addressed by articulating the problem in terms of tension and analyzing it in the CAFCR framework.

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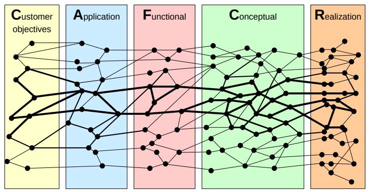


Overview of the reasoning approach

1. select starting point:
   ! actual dominant need or problem

2. create insight:
   + submethod in one of CAFCR views
   + qualities checklist

3. deepen insight via facts:
   + via tests, measurements, simulations
   + story telling

4. broaden insight via questions:
   + why
   + what
   + how

5. define and extend the thread:
   ? what is the most important / valuable
   ? what is the most critical / sensitive
   ! look for the conflicts and tension

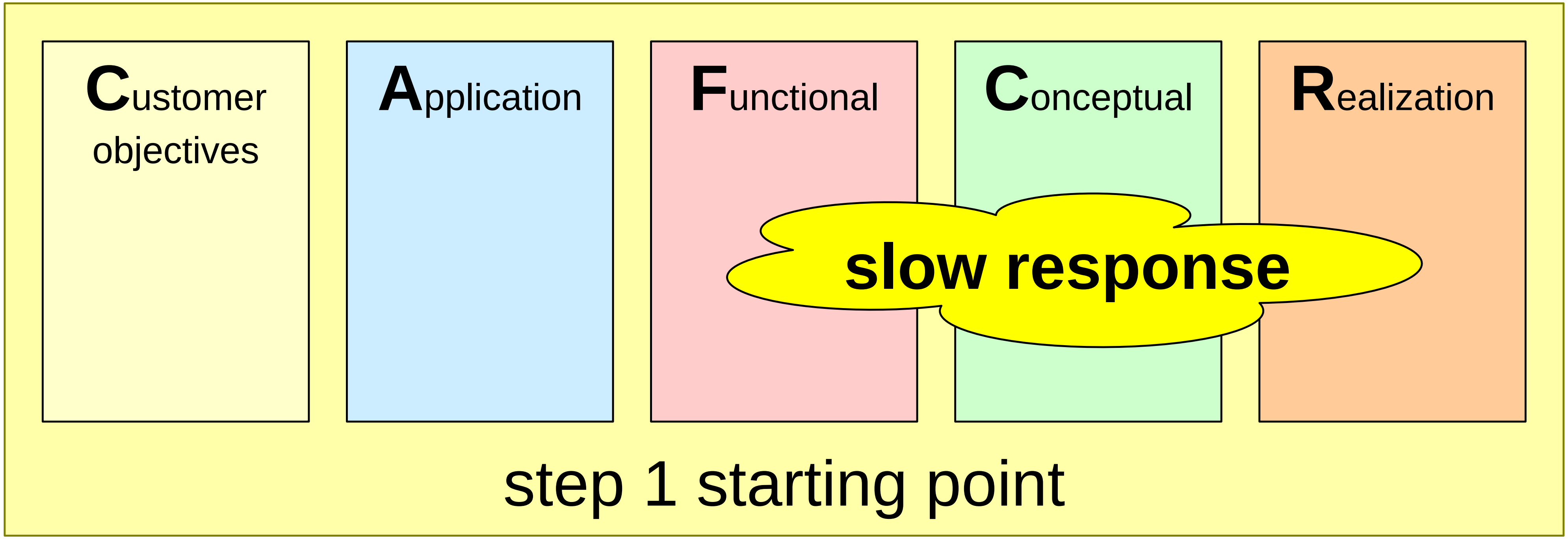
continuously

consolidate in simple models

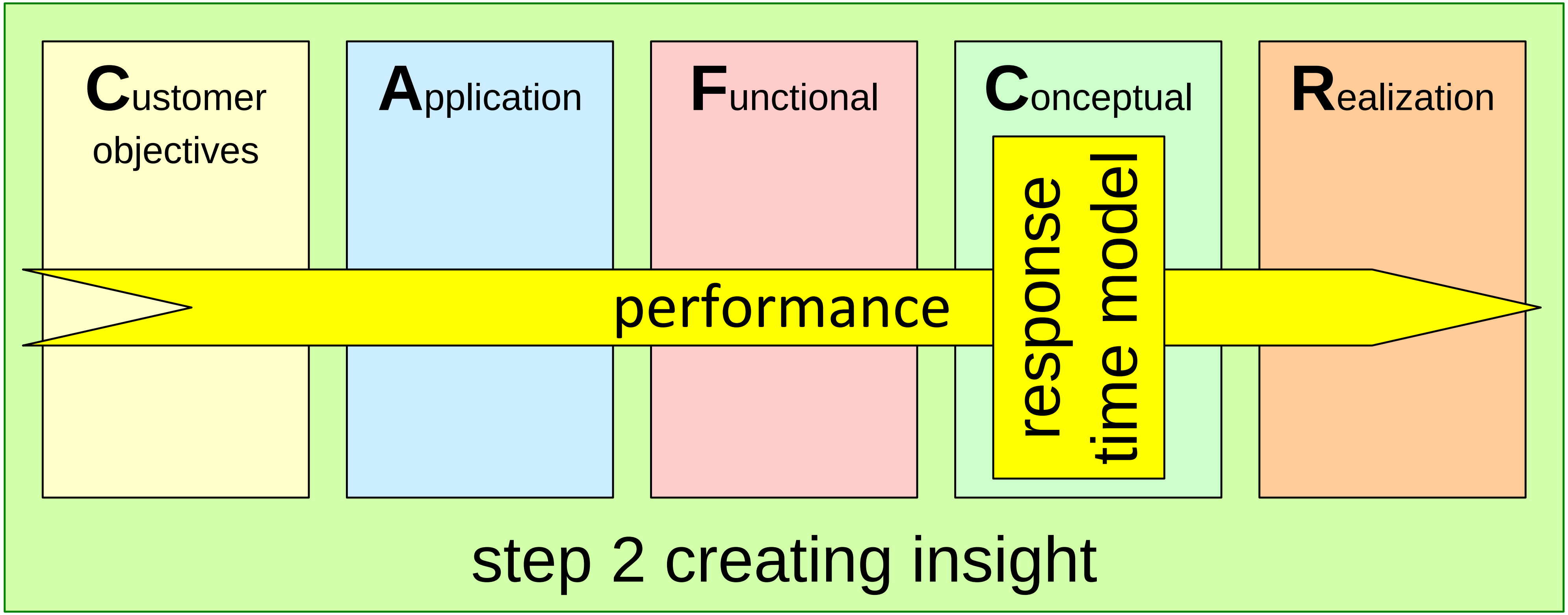
communicate to stakeholders

refactor documentation

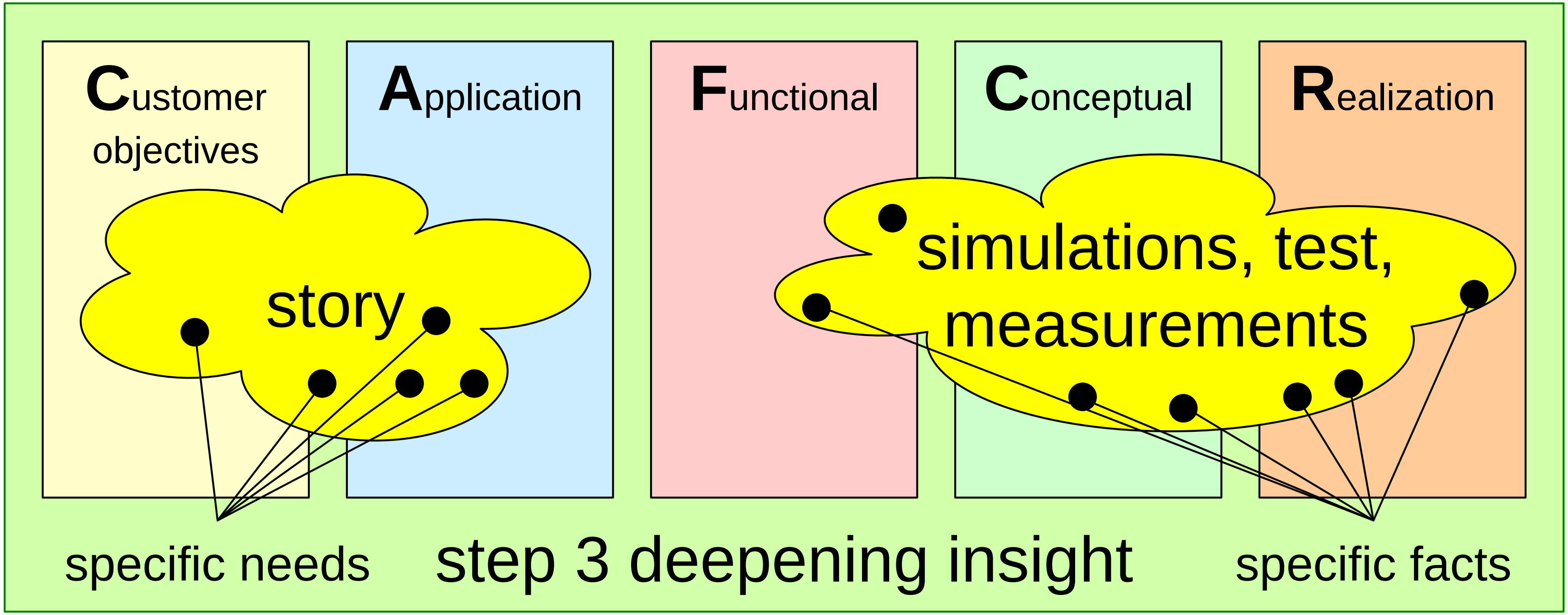
From starting point to insight



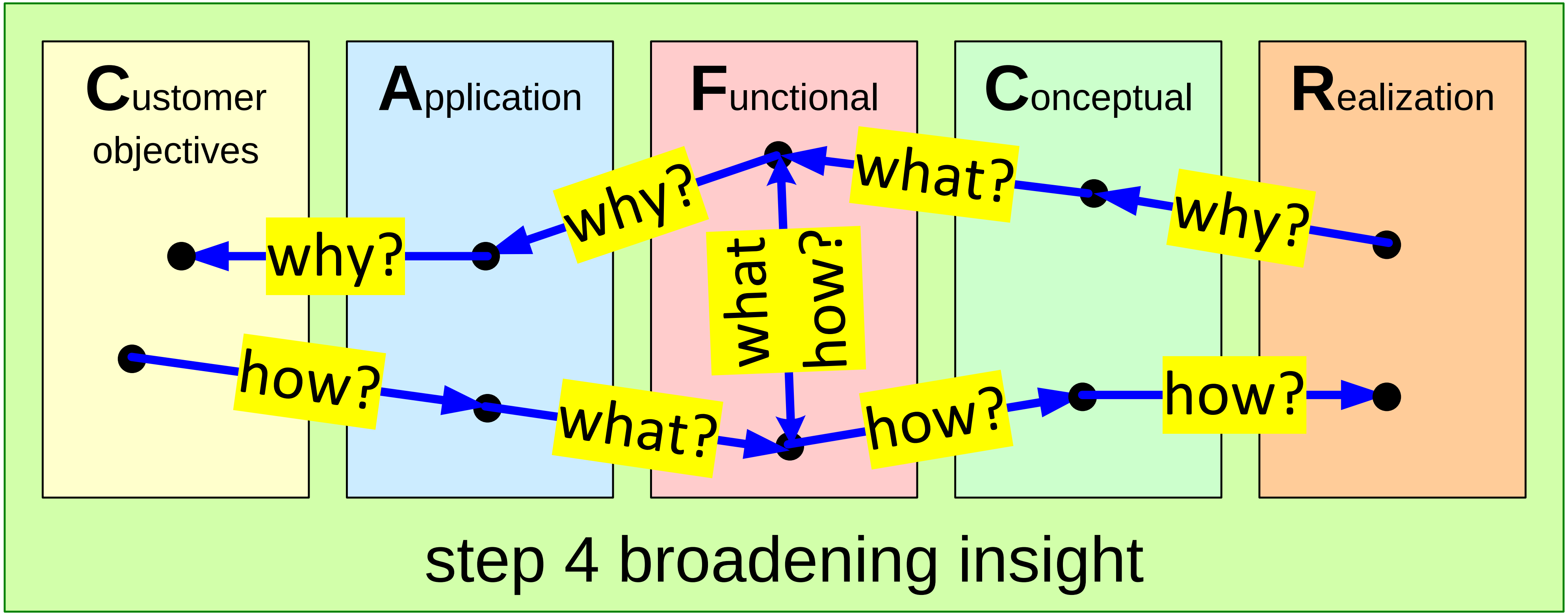
Creating Insight



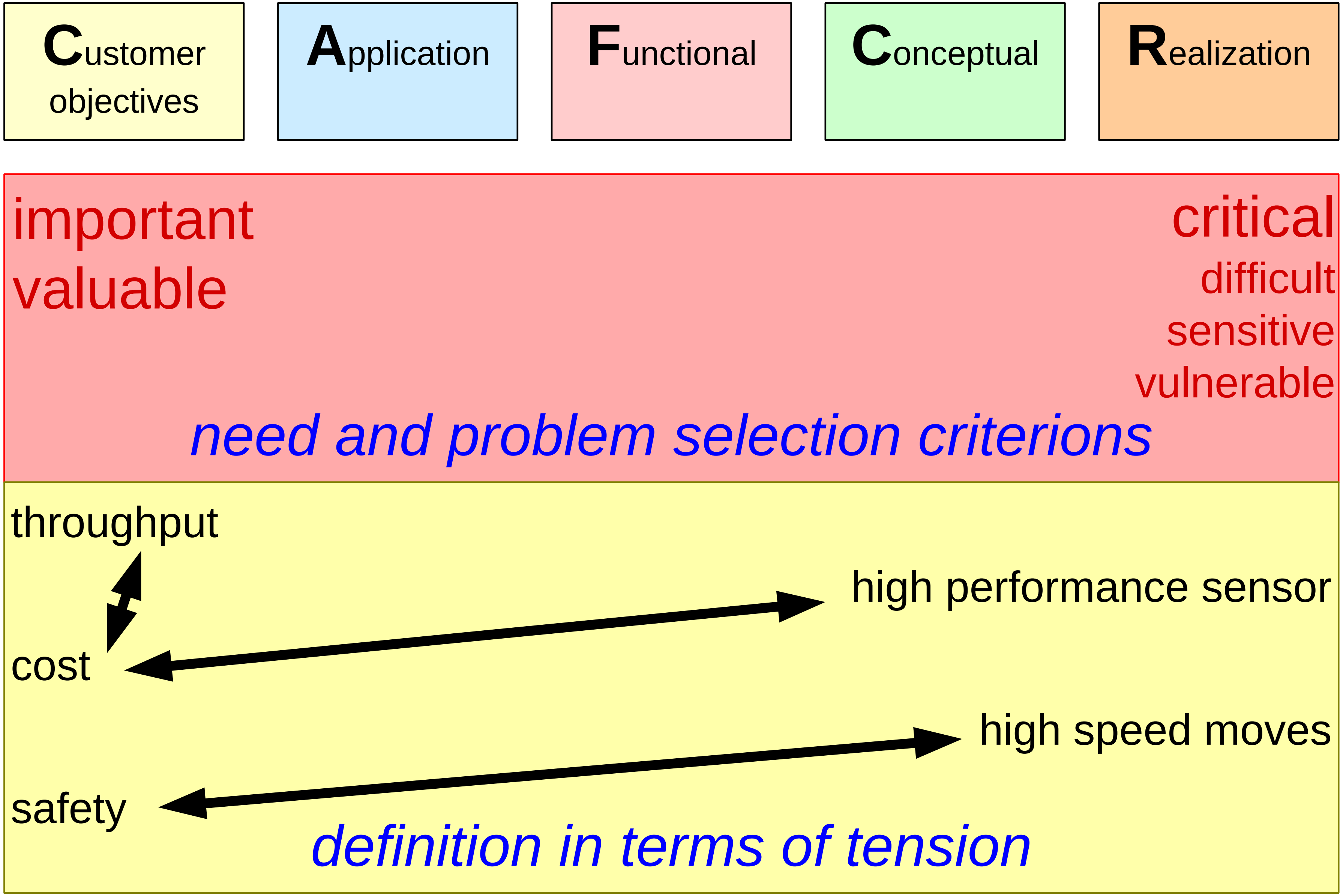
Deepening Insight



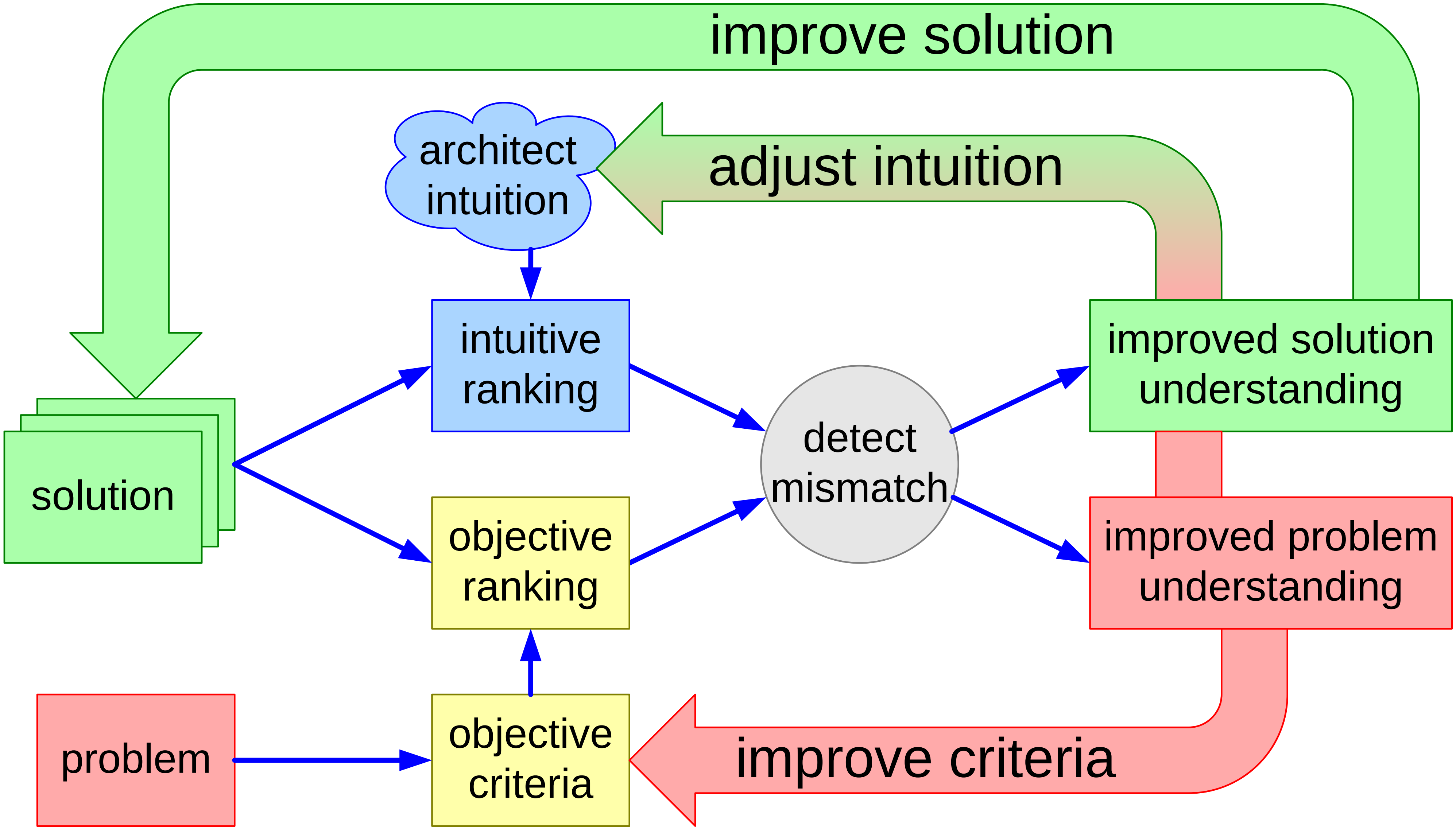
Broadening Insight



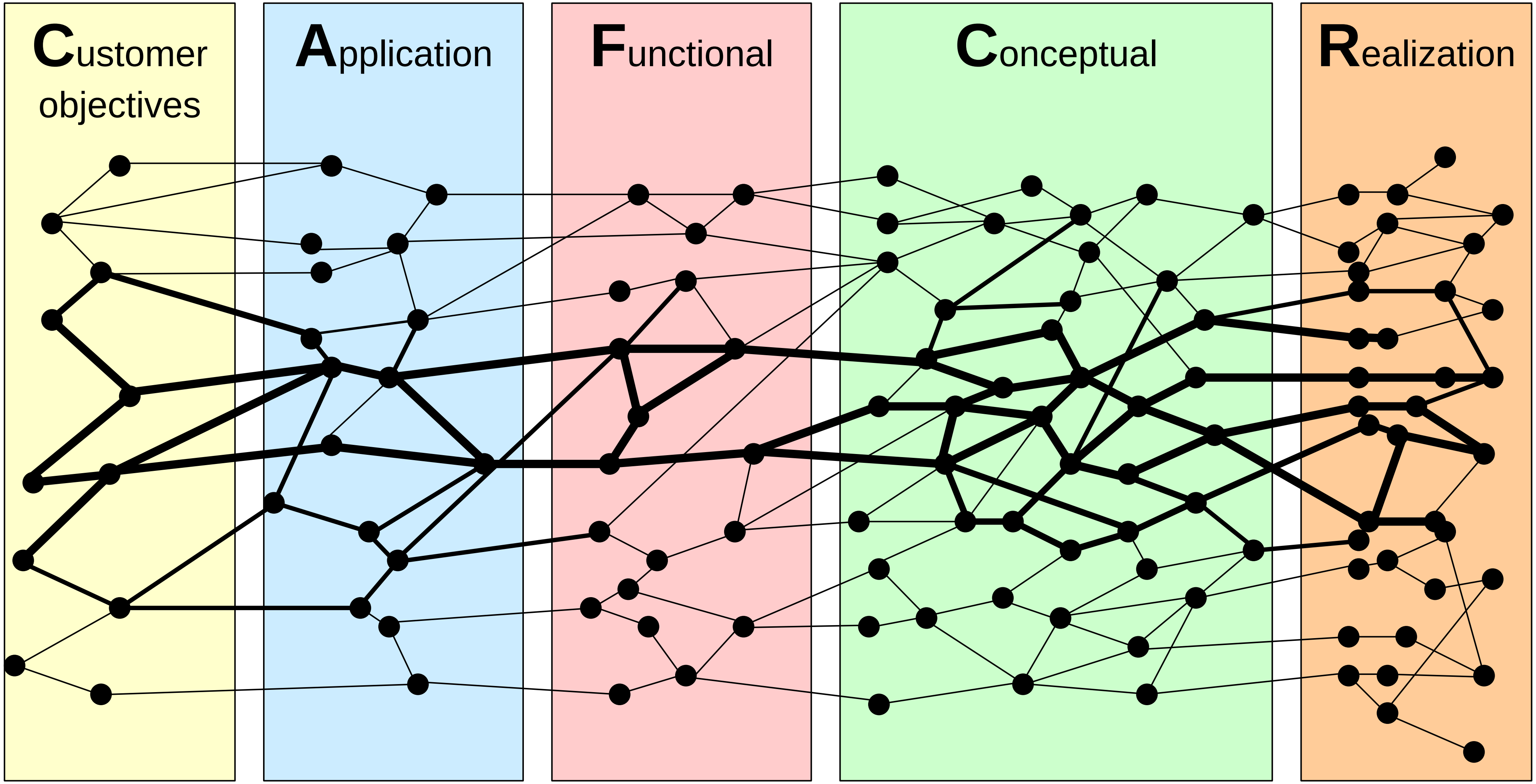
Problem identification and articulation



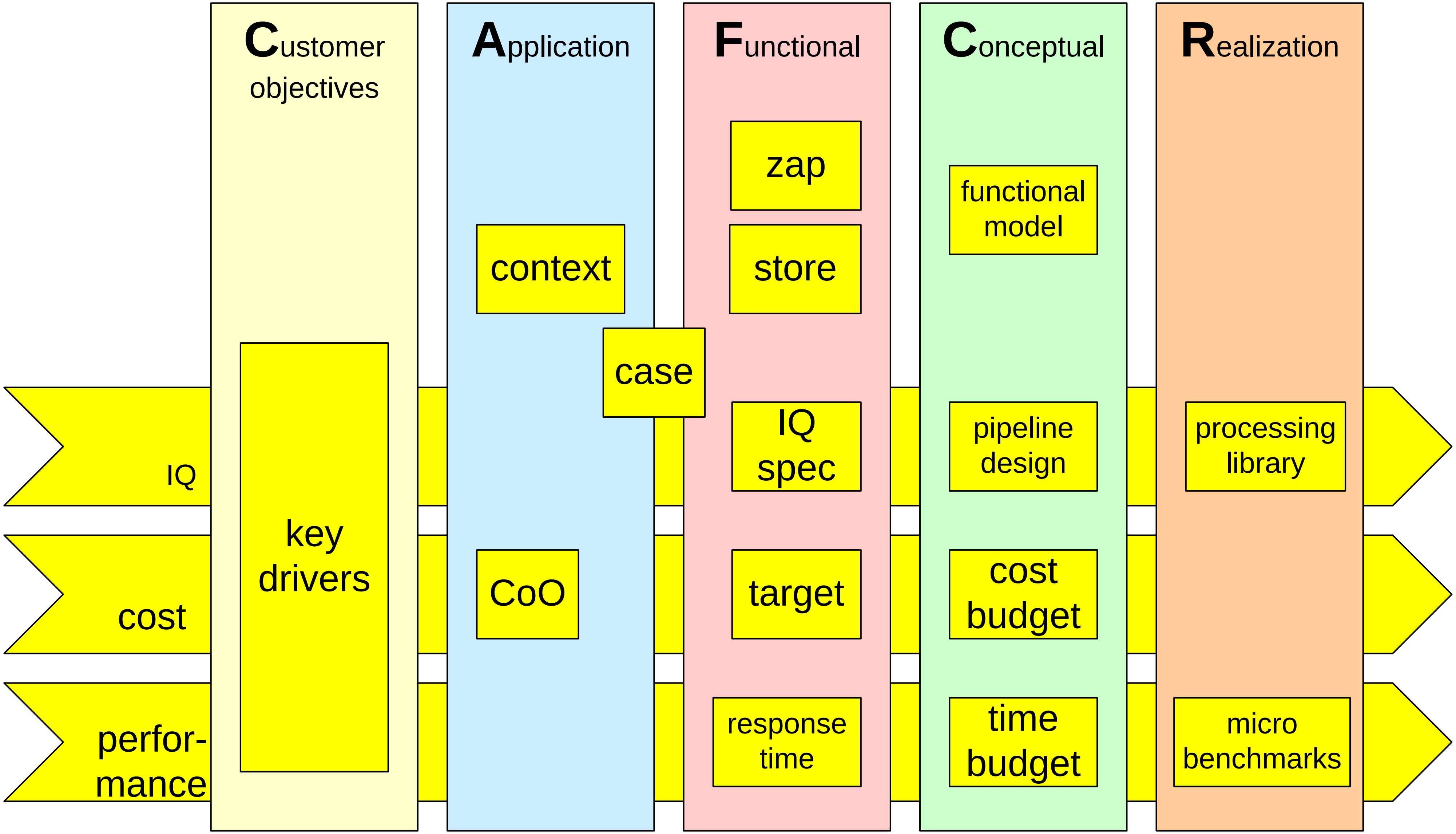
Iteration during the analysis



Thread of related issues



Documentation and communication structure



Threads of reasoning illustrated by medical imaging case

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

e-mail: gaudisite@gmail.com

www.gaudisite.nl

Abstract

The medical imaging workstation case is introduced. An architecting method based on the CAFCR viewpoints is explained, consisting of 4 elements:

- the CAFCR viewpoints
- qualities as integrating needles
- story telling
- threads of reasoning

A thread of reasoning is build up in steps, based on this case. The underlying reasoning is explained.

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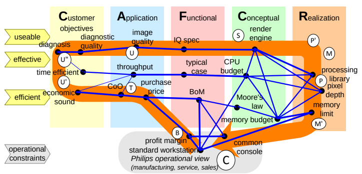
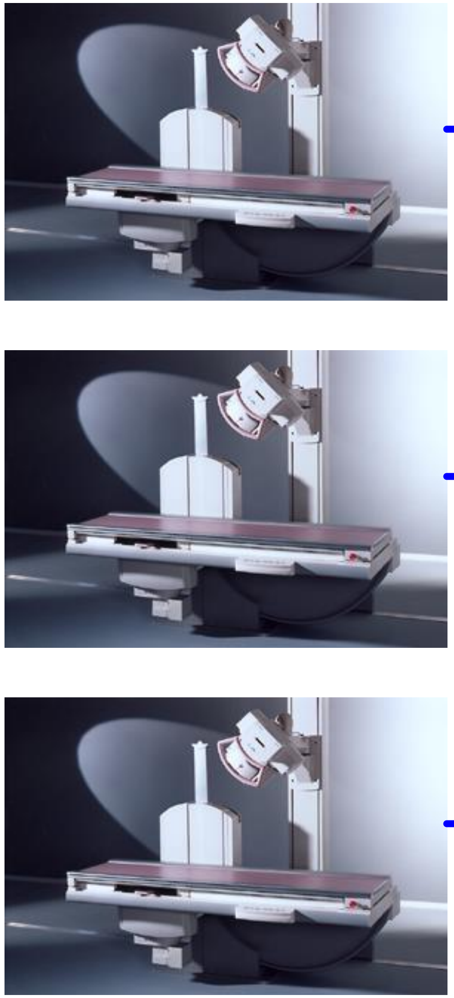
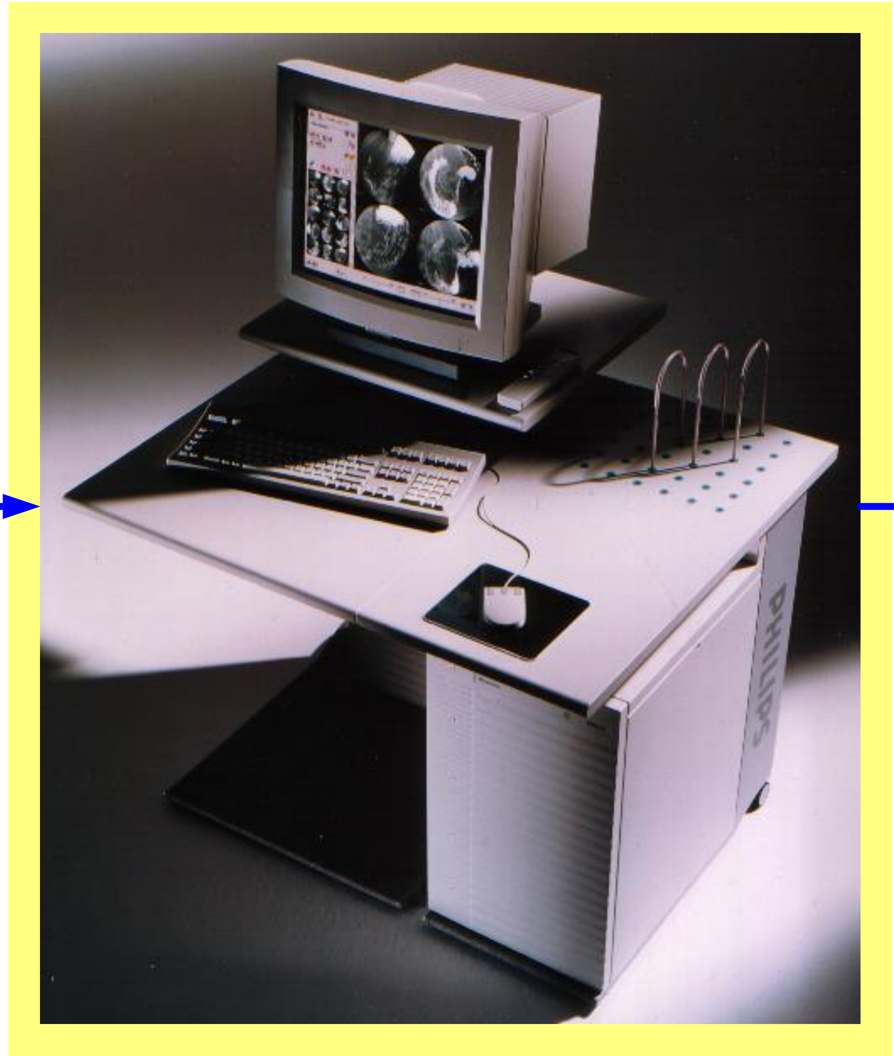


cost revisited in context of clinical needs and realization constraints; note: original threads are significantly simplified

Easyvision serving three URF examination rooms



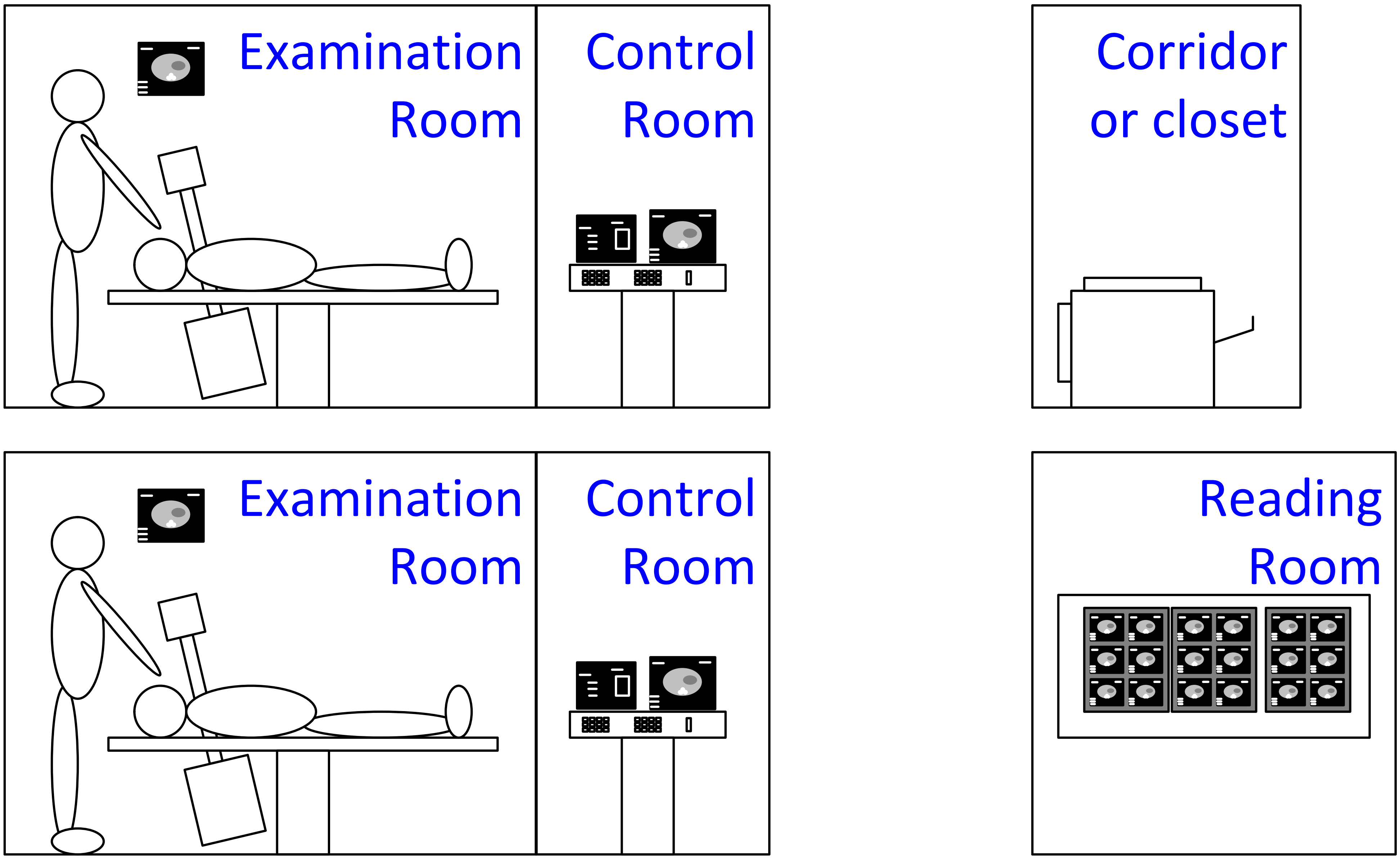
URF-systems



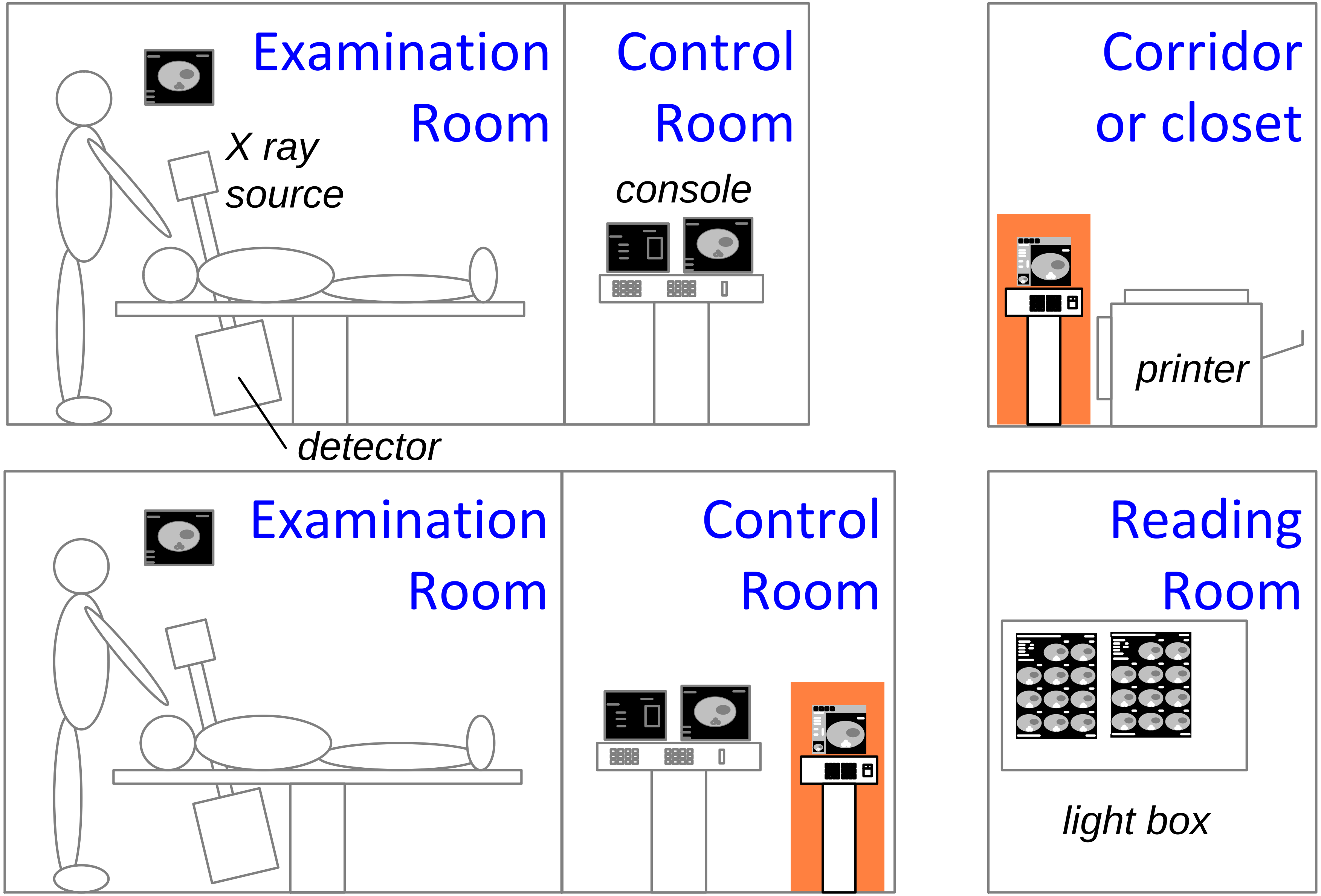
EasyVision: Medical Imaging Workstation

typical clinical image (intestines)

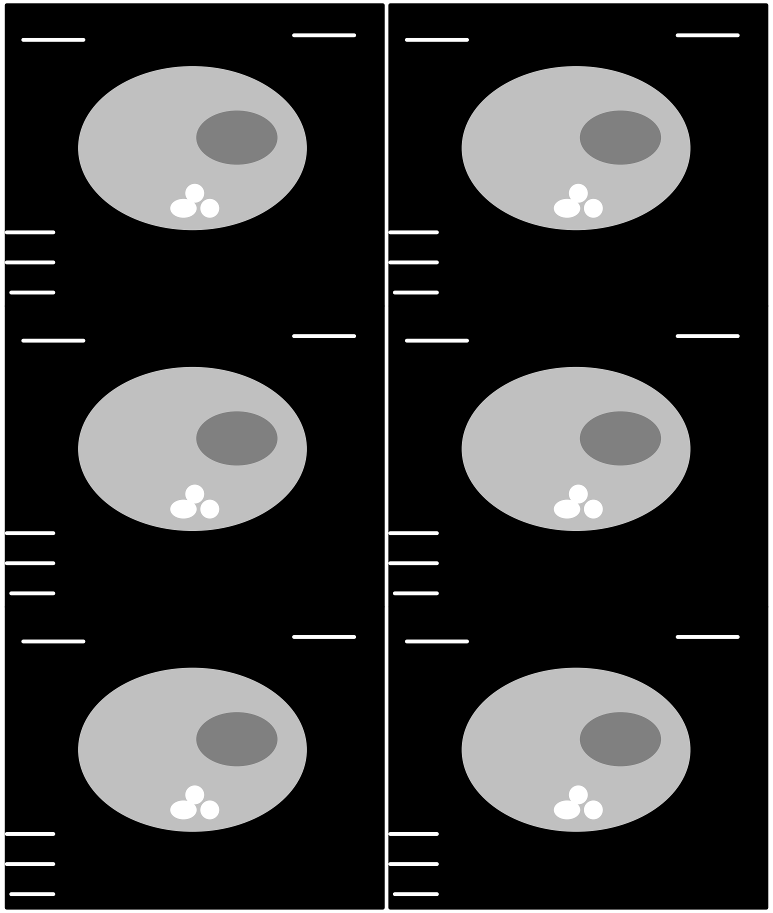
X-ray rooms from examination to reading around 1990



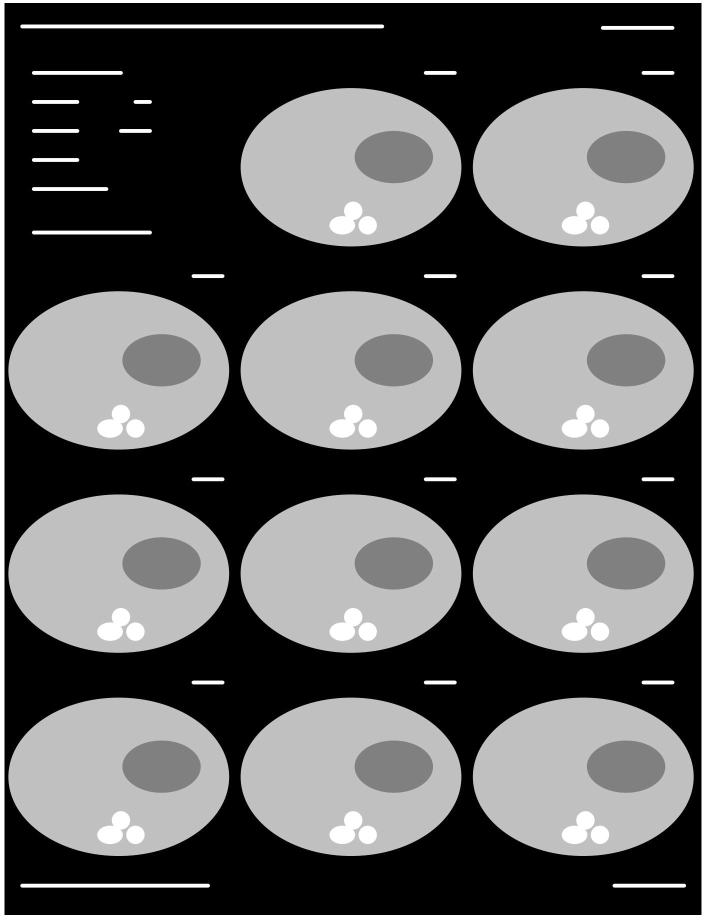
X-ray rooms with Easyvision applied as printserver



Comparison screen copy versus optimized film



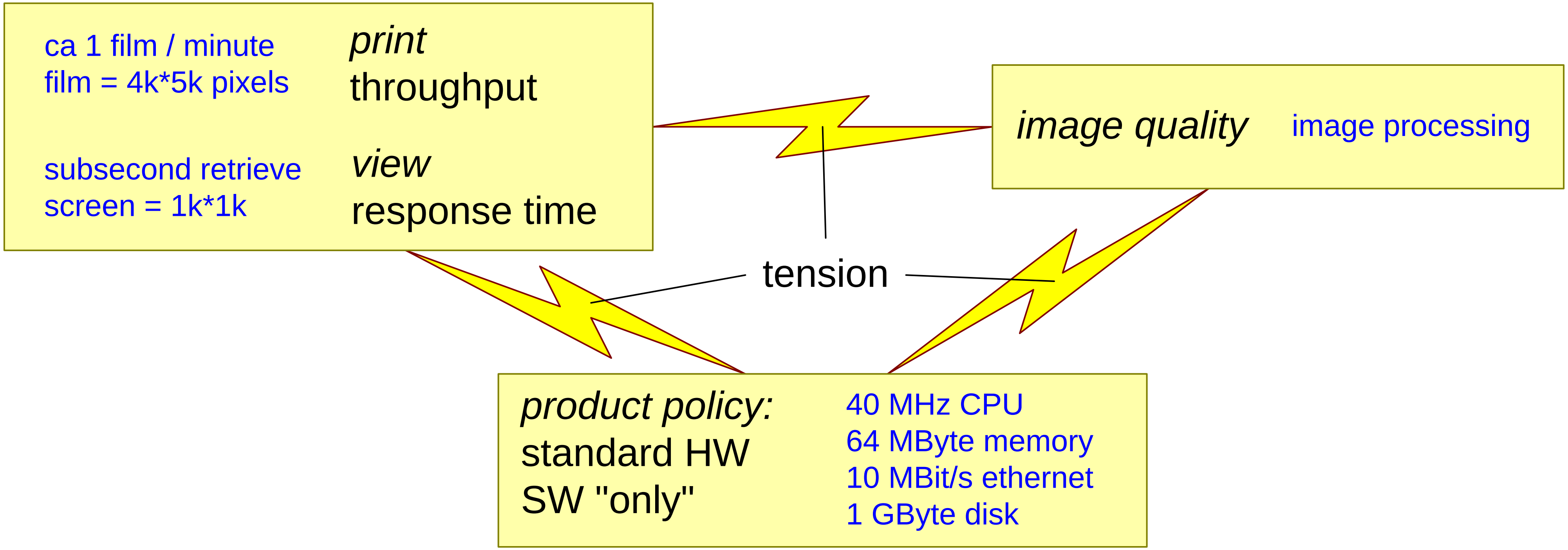
old: screen copy



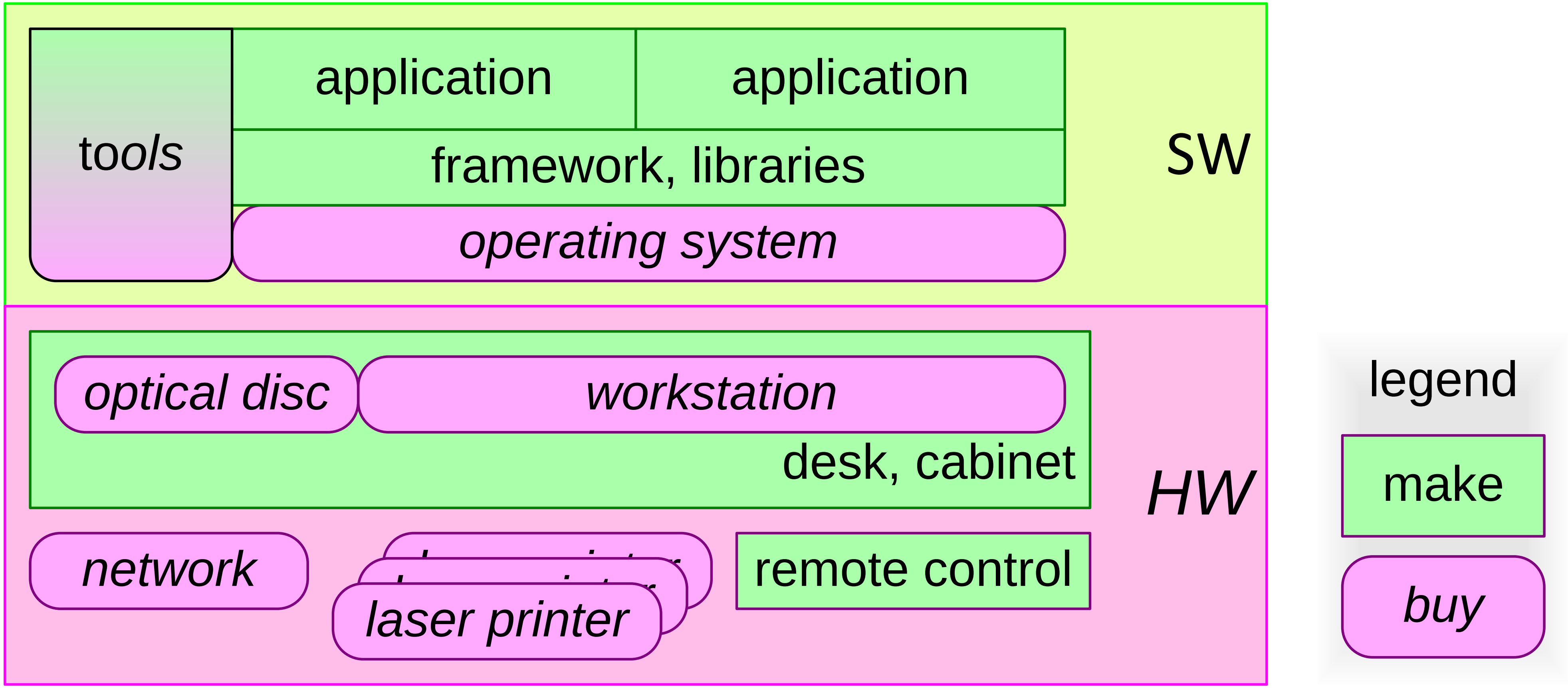
new: SW formatting

20 to 50% less film needed

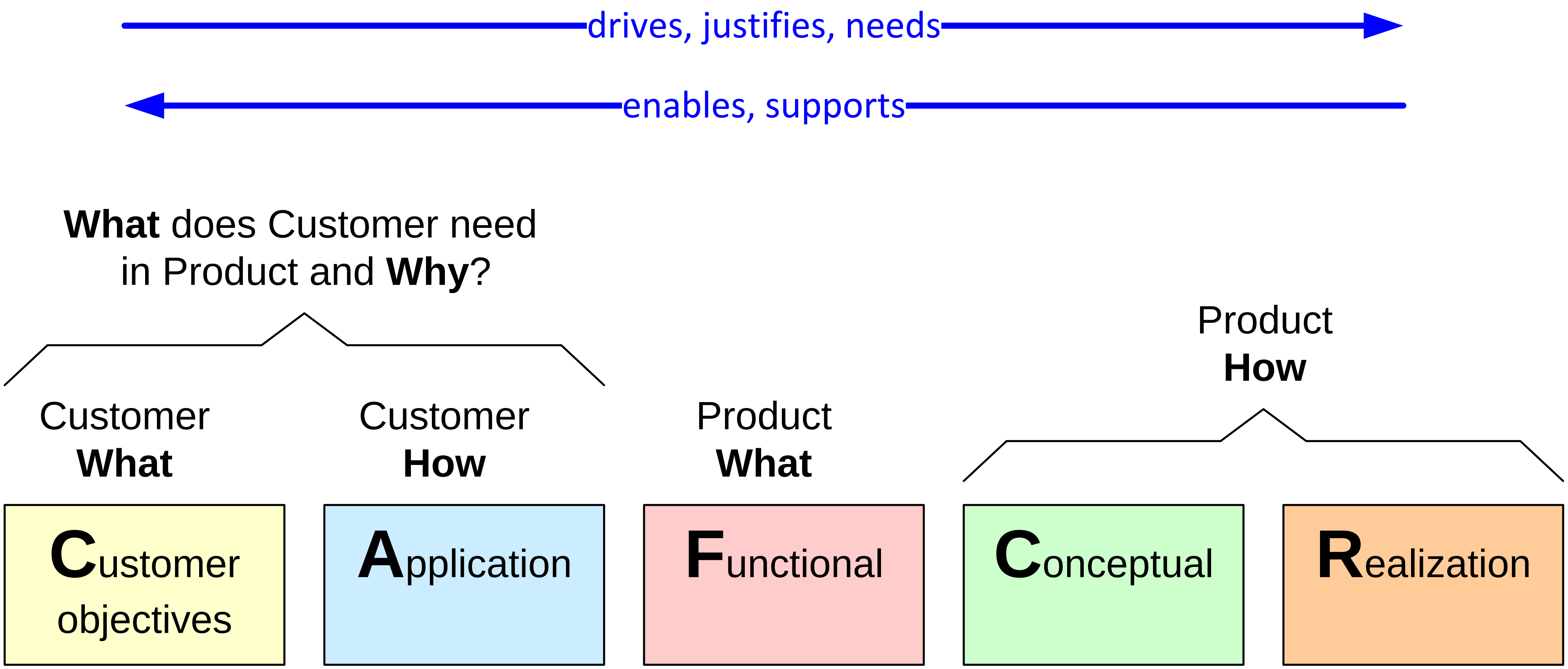
Challenges for product creation



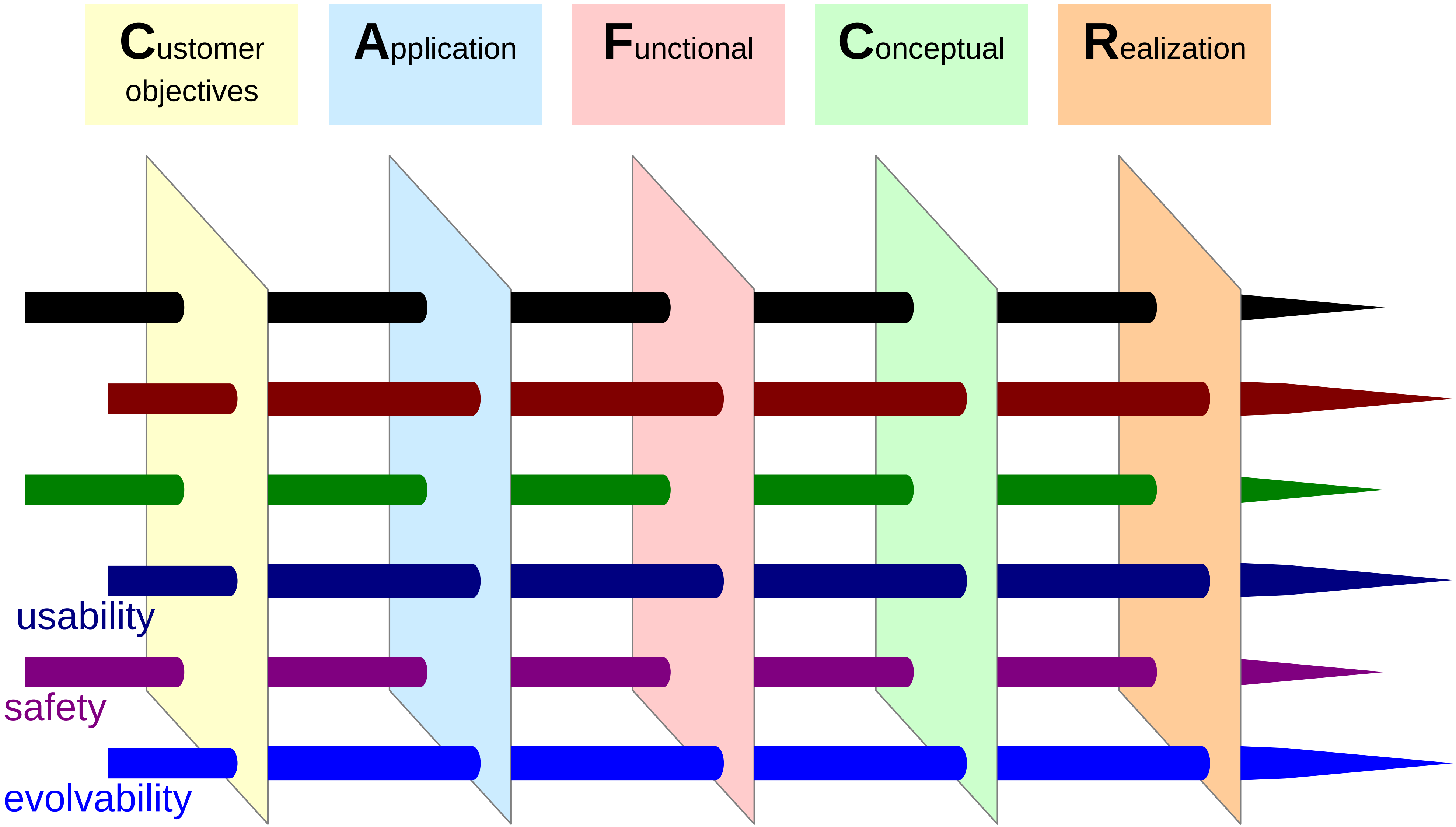
Top level decomposition



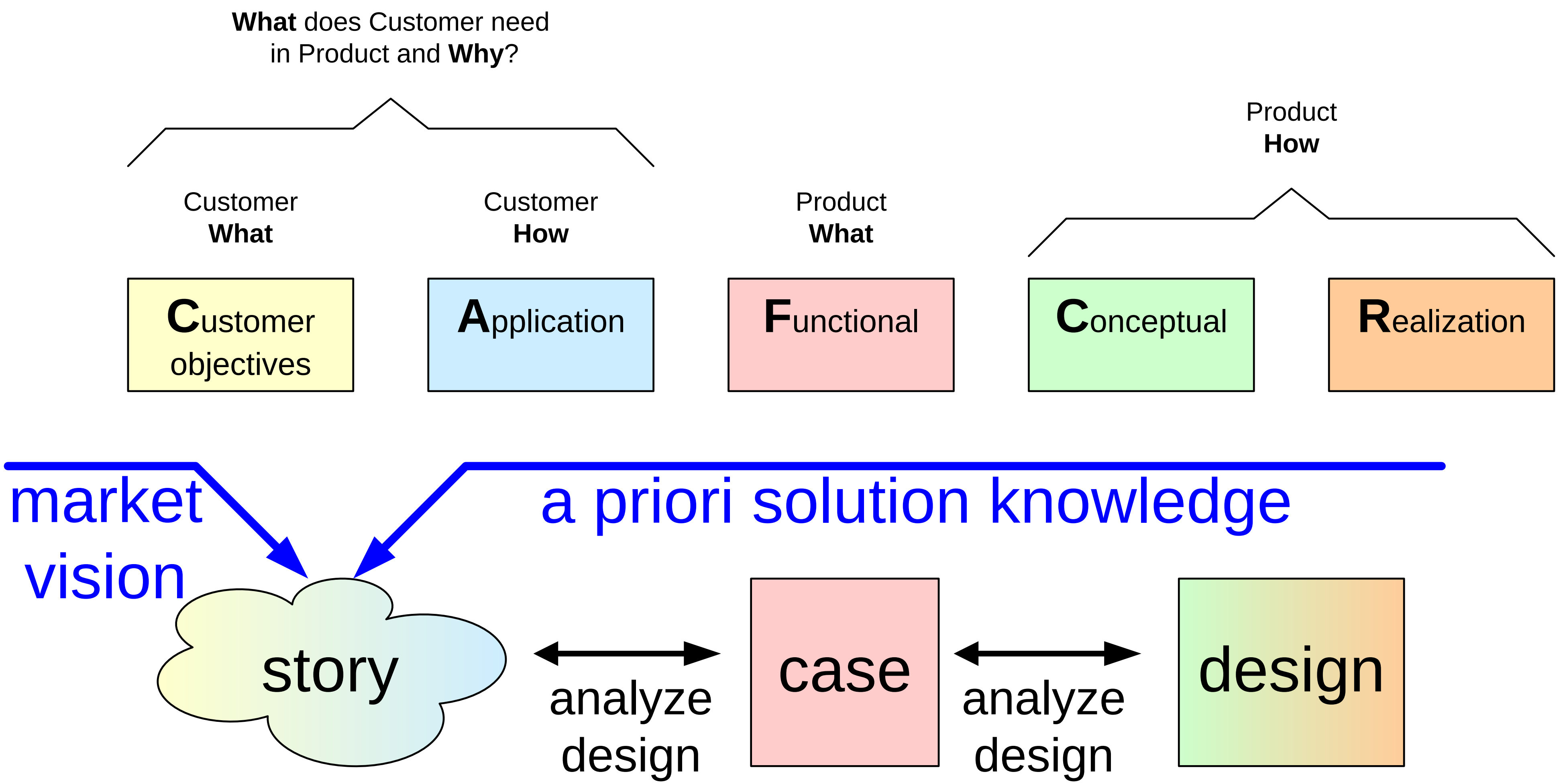
CAFCR viewpoints



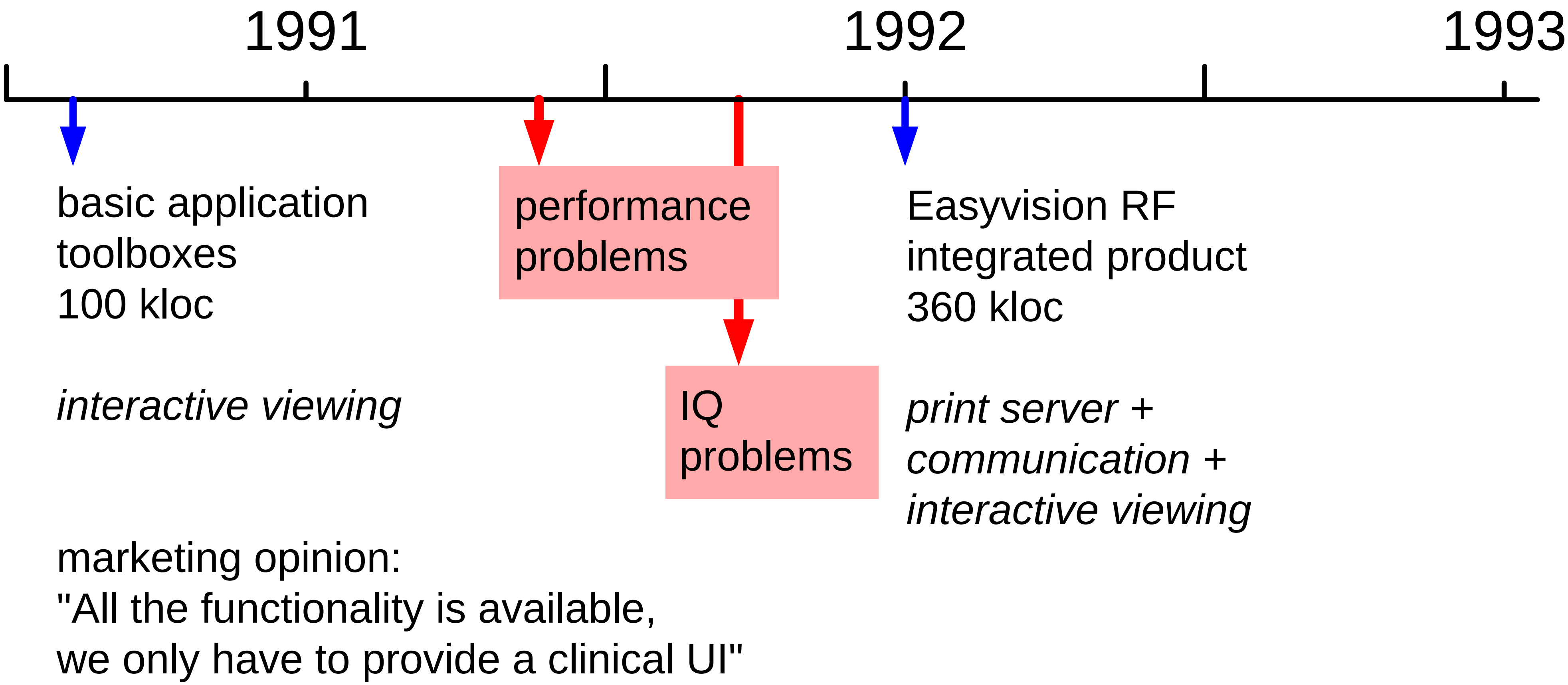
Quality needles as generic integrating concepts



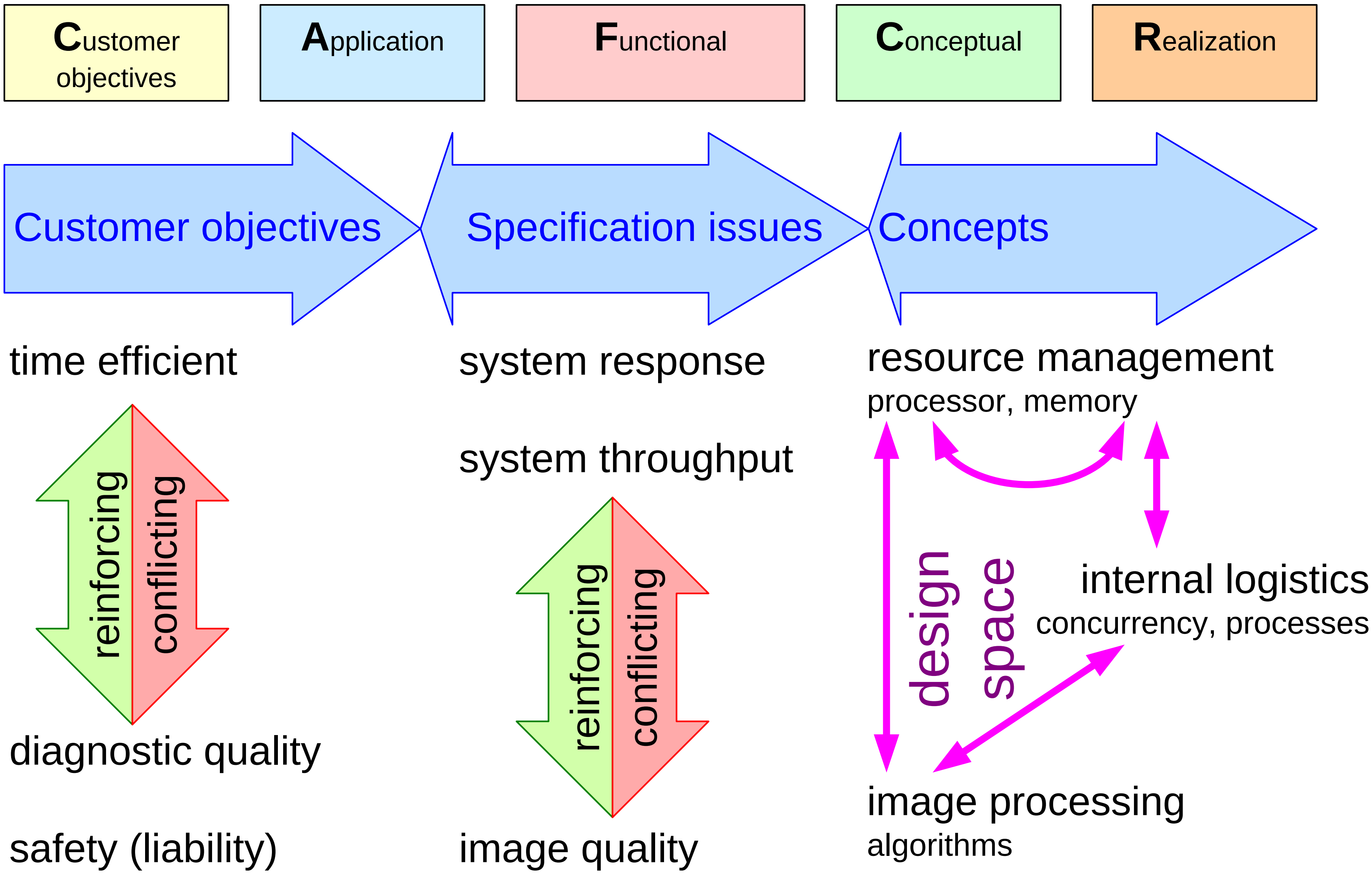
From story to design



Chronology of Easyvision RF R1 development



Thread of reasoning based on efficiency-quality tension

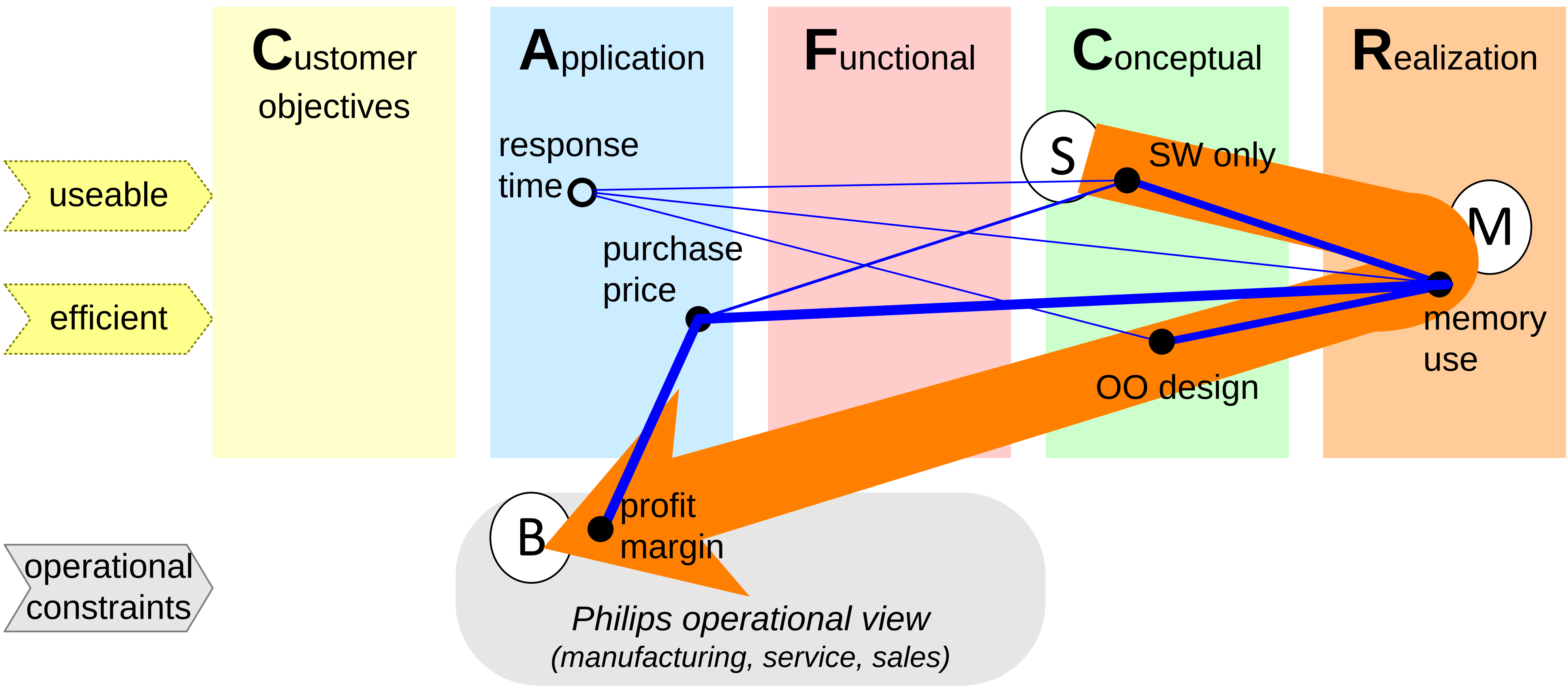


Technology innovations

performance
cost

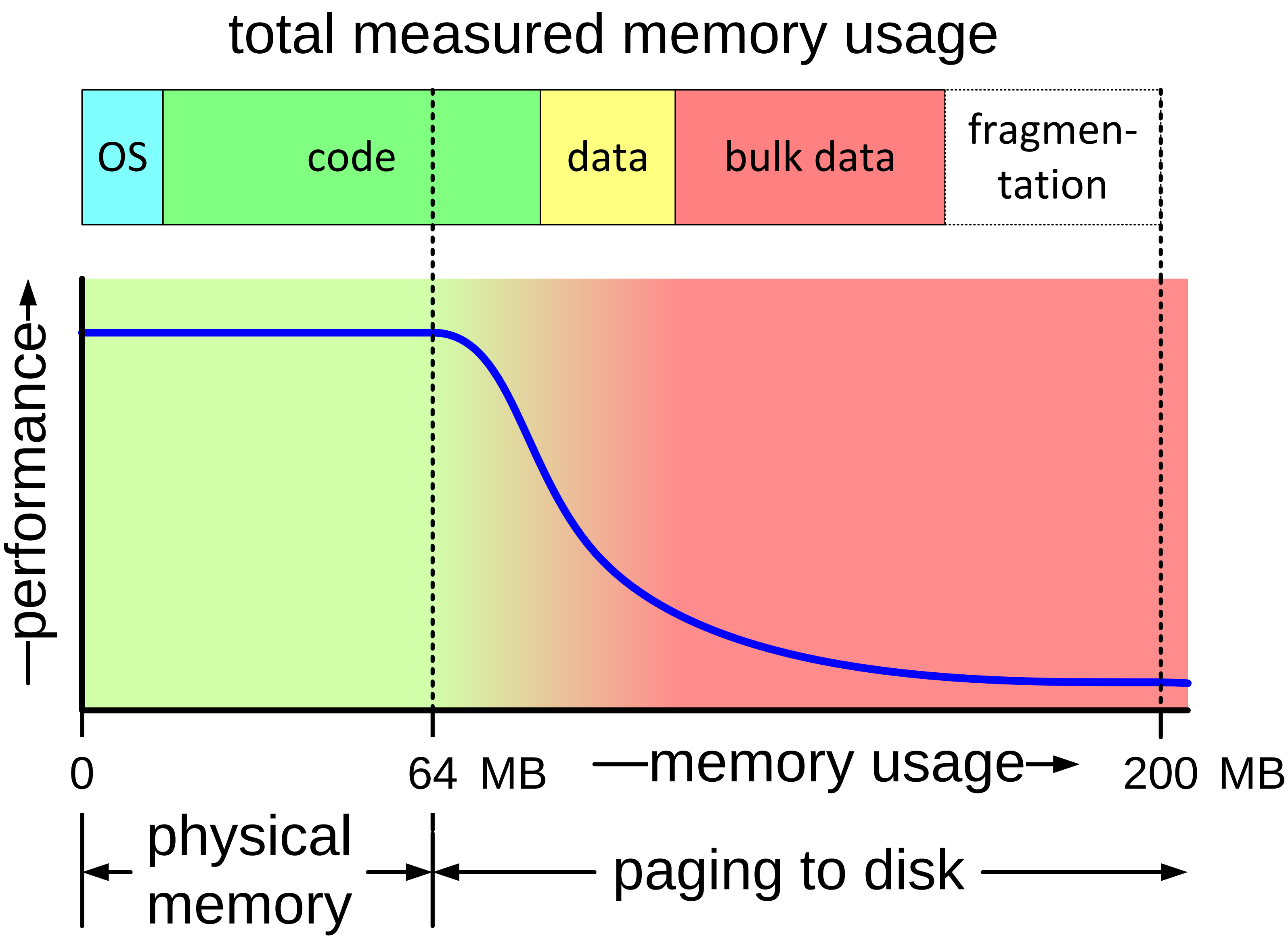
- standard UNIX based workstation
- full SW implementation, more flexible
- object oriented design and implementation (Objective-C)
- graphical User Interface, with windows, mouse etcetera
- call back scheduling, fine-grained notification
- data base engine, fast, reliable and robust
- extensive set of toolboxes
- property based configuration
- multiple coordinate spaces

Thread of reasoning; introvert phase

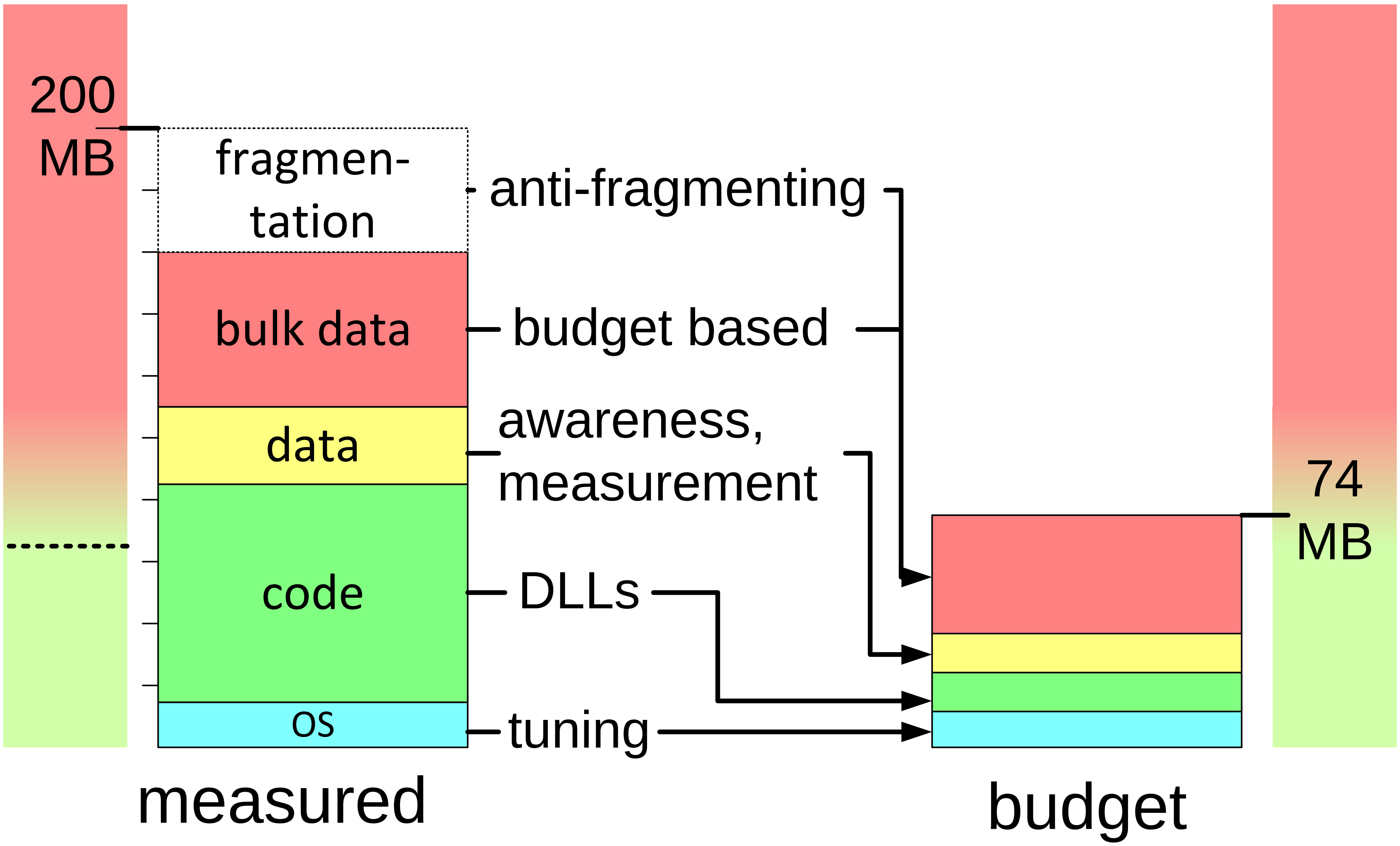


Introvert view: cost and impact of new technologies

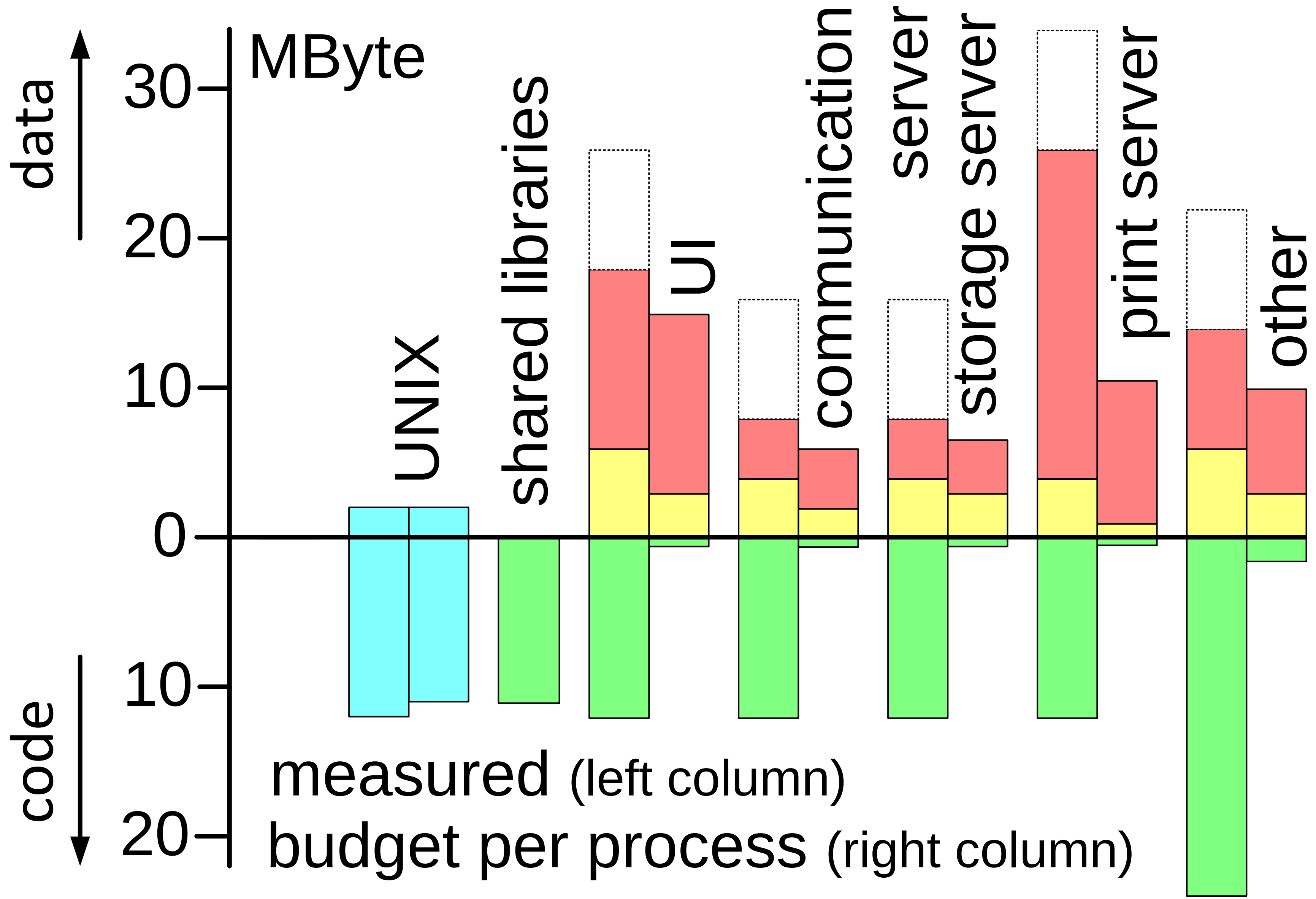
Memory usage half way R1



Solution of memory performance problem



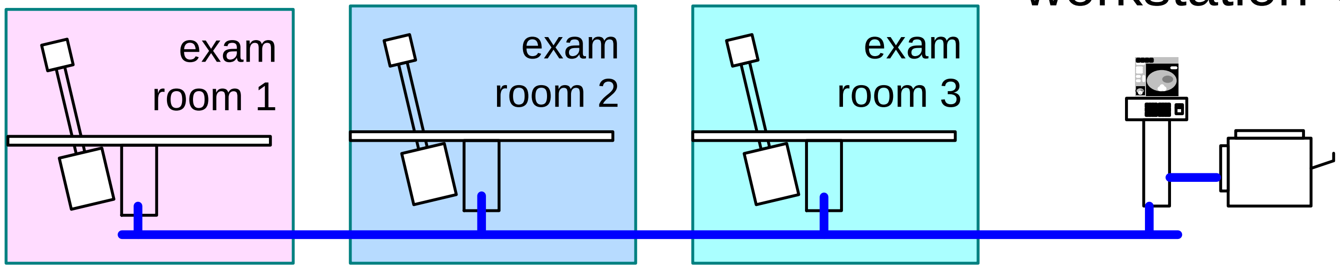
Visualization memory use per process



Typical case URF examination

3 examination rooms connected to

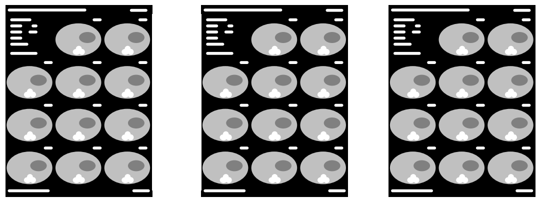
1 medical imaging workstation + printer



examination room: average 4 interleaved examinations / hour

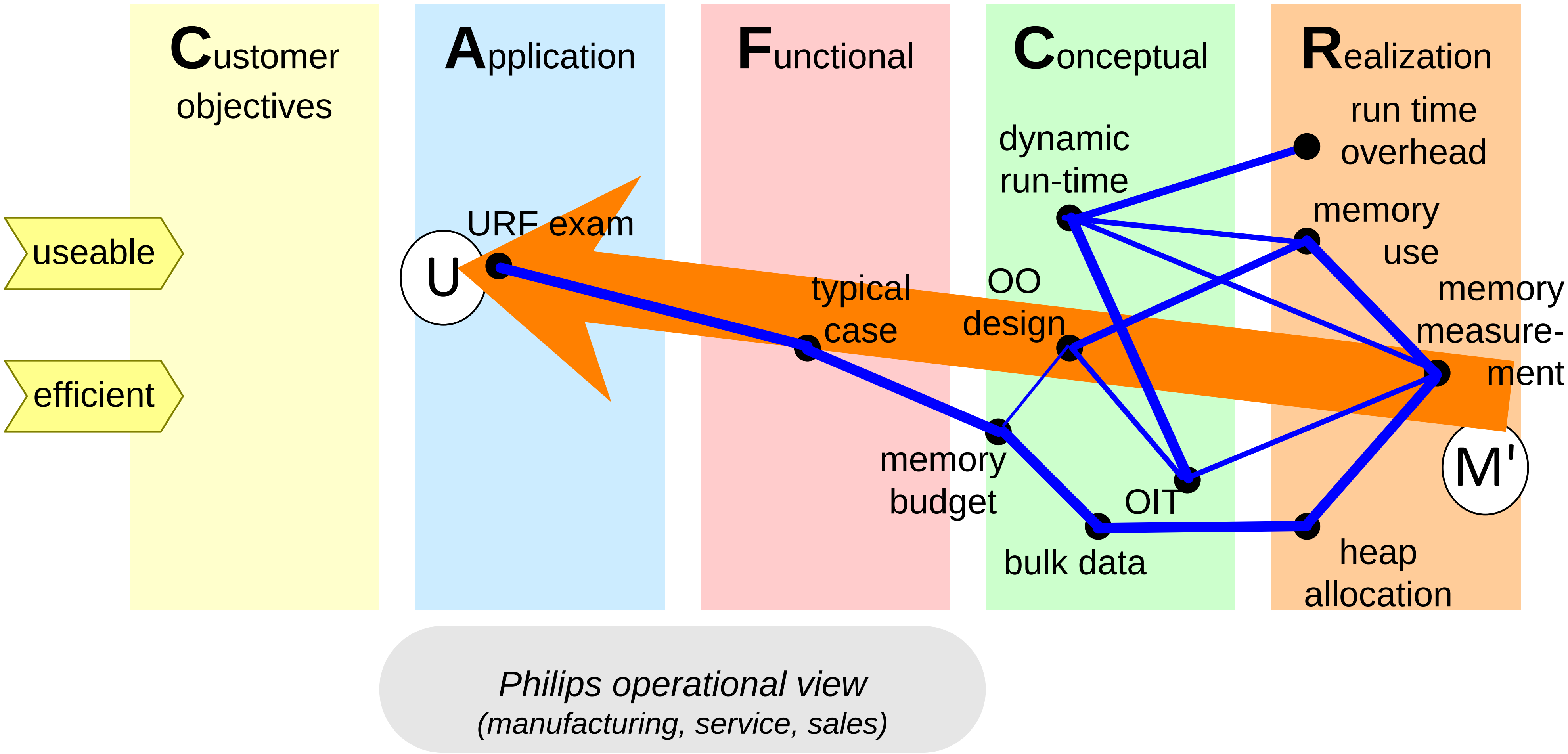
image production: 20 1024^2 8 bit images per examination

film production: 3 films of 4k*5k pixels each



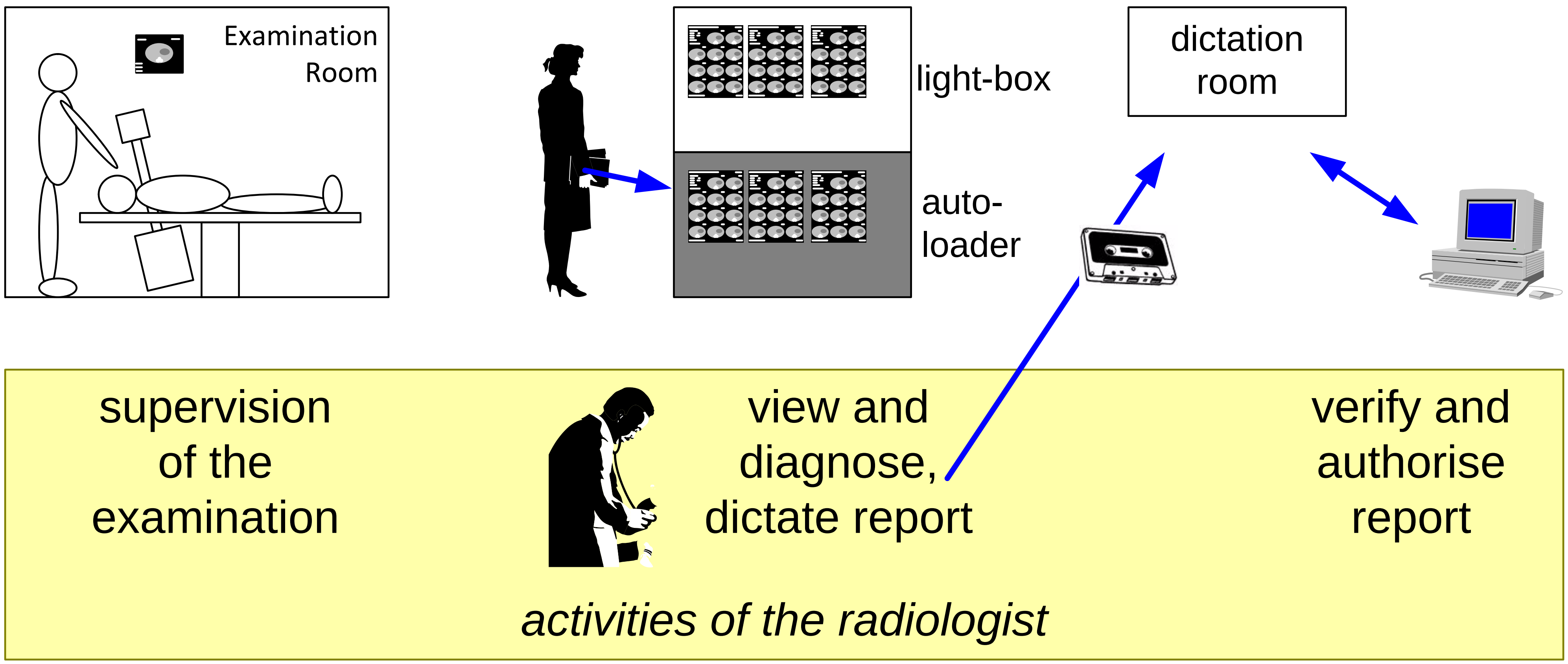
high quality output (bi-cubic interpolation)

Thread of reasoning; phase 2

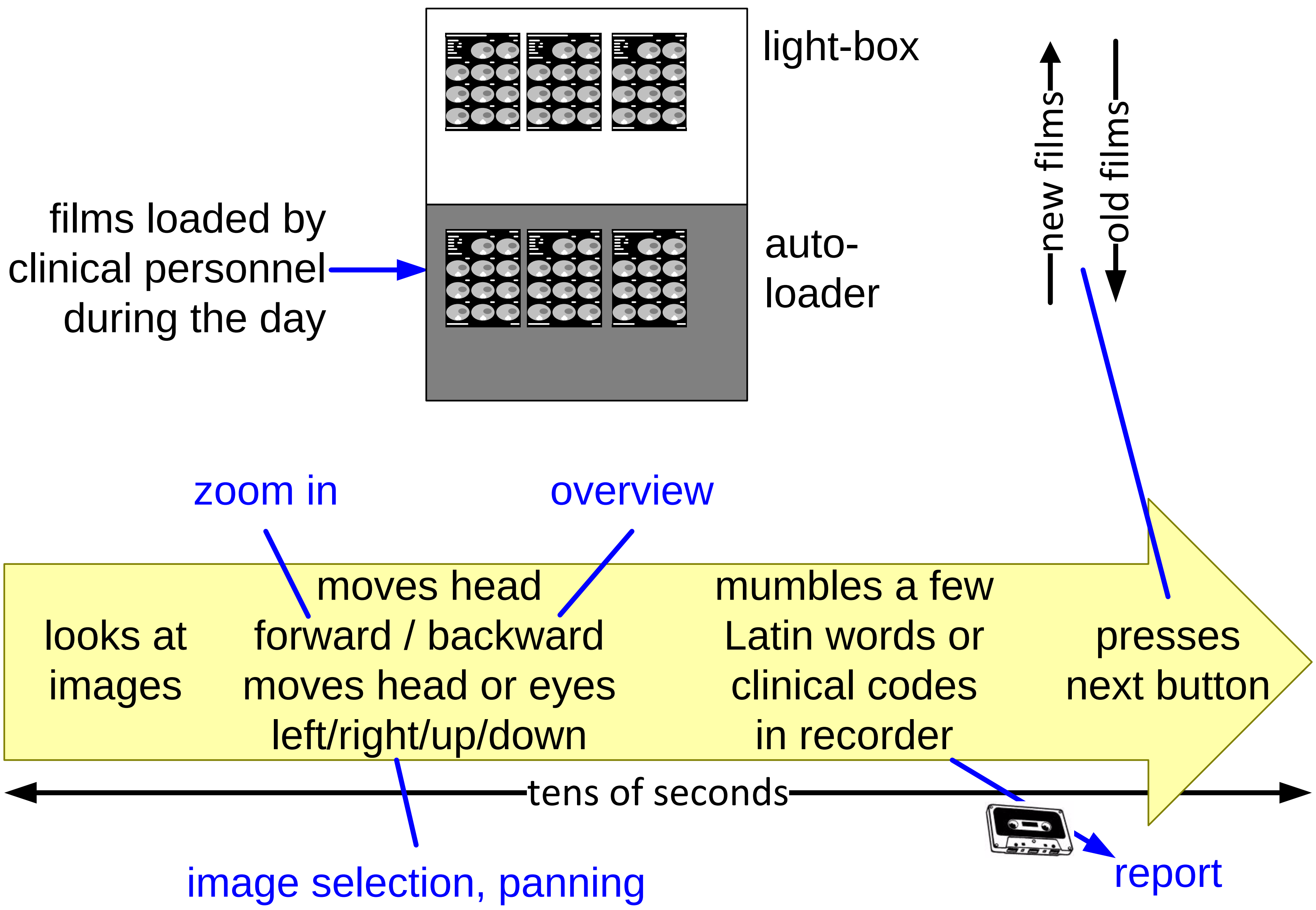


How to measure memory, how much is needed?
from introvert to extrovert

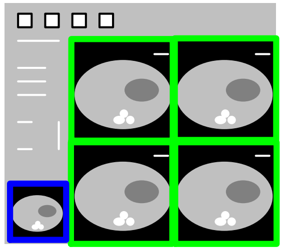
Radiologist workspots and activities



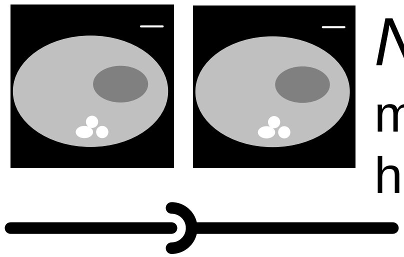
Diagnosis in tens of seconds



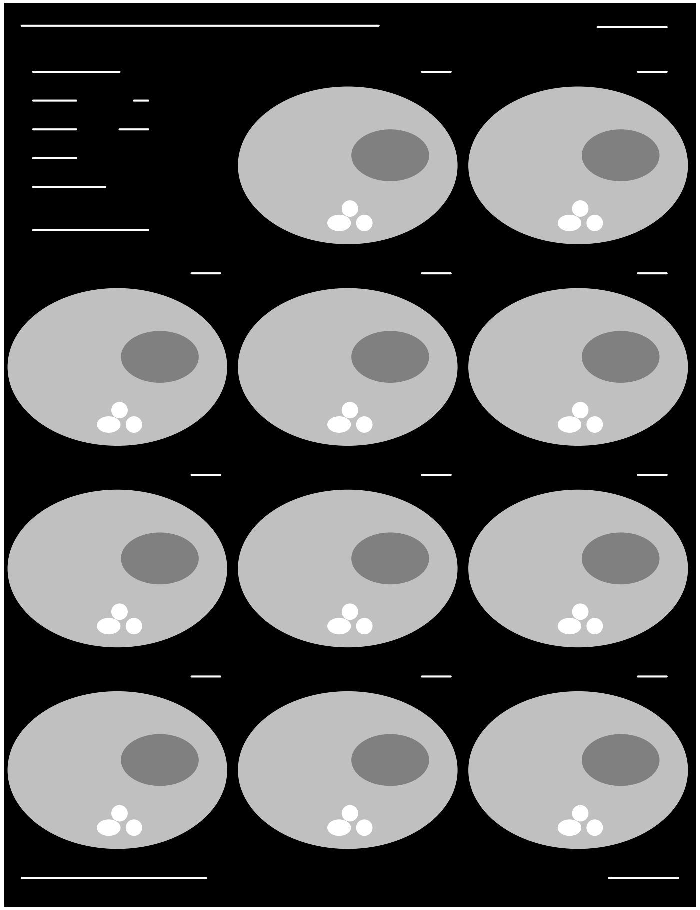
Rendered images at different destinations



Screen:
low resolution
fast response

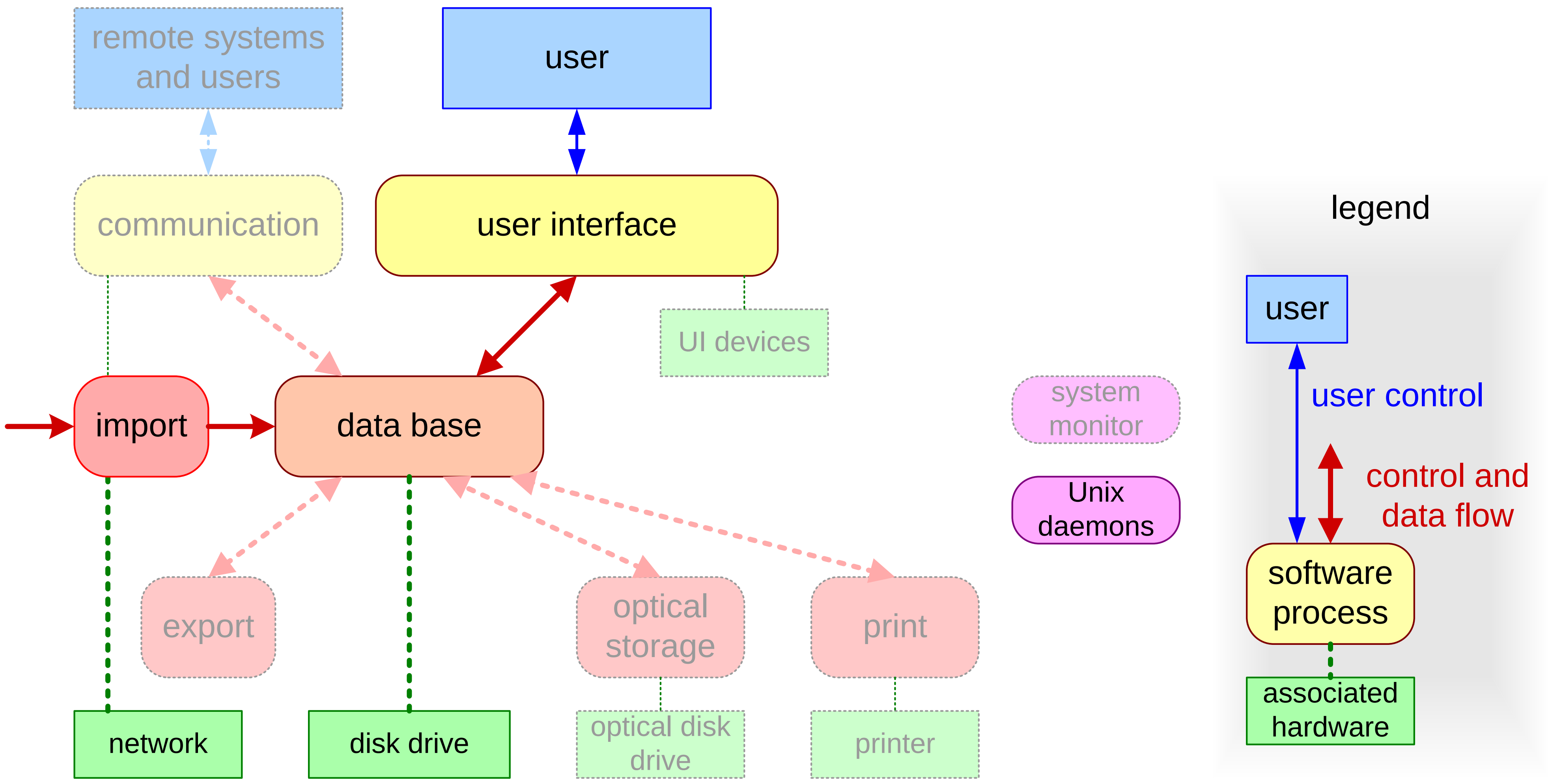


Network:
medium resolution
high throughput

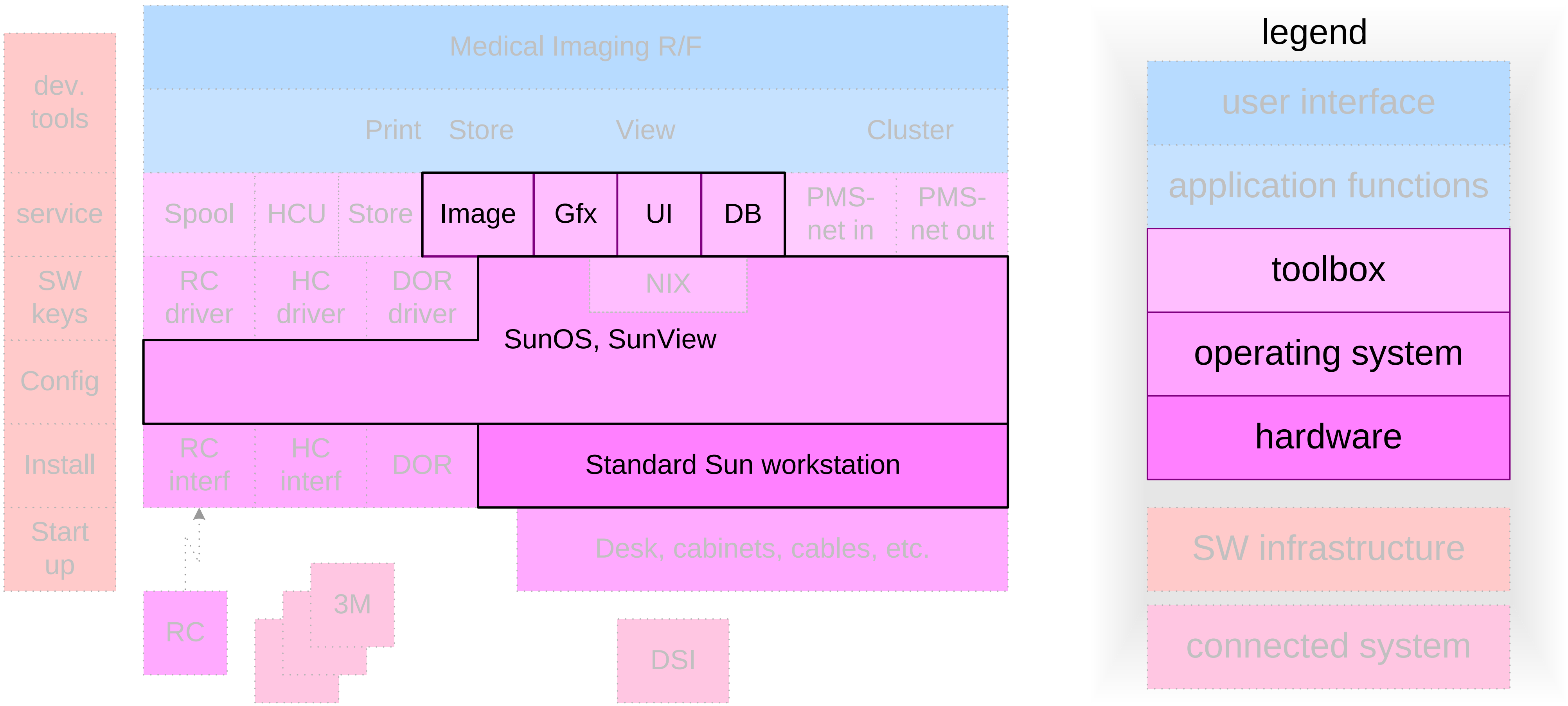


Film:
high resolution
high throughput

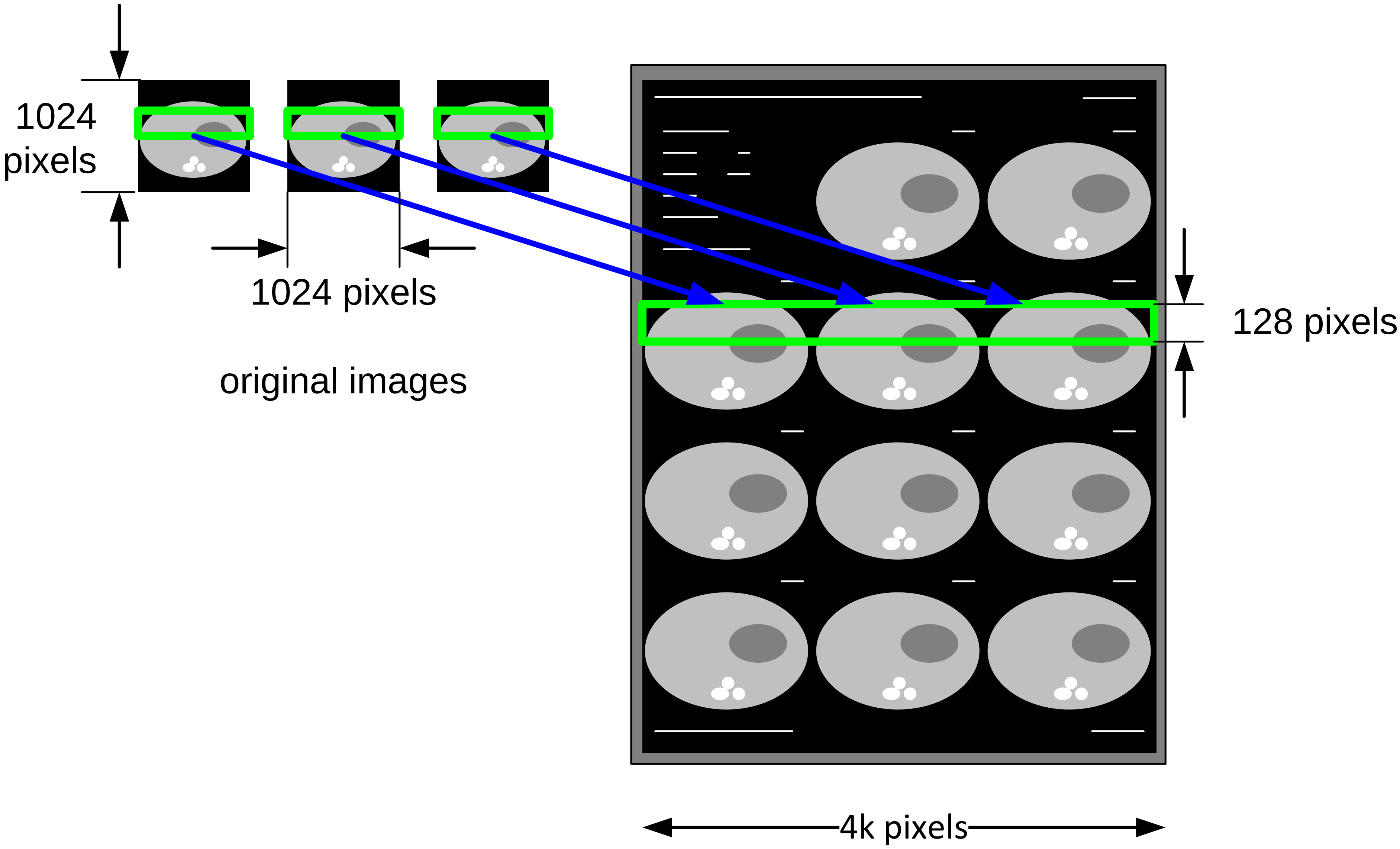
SW Process structure 1991



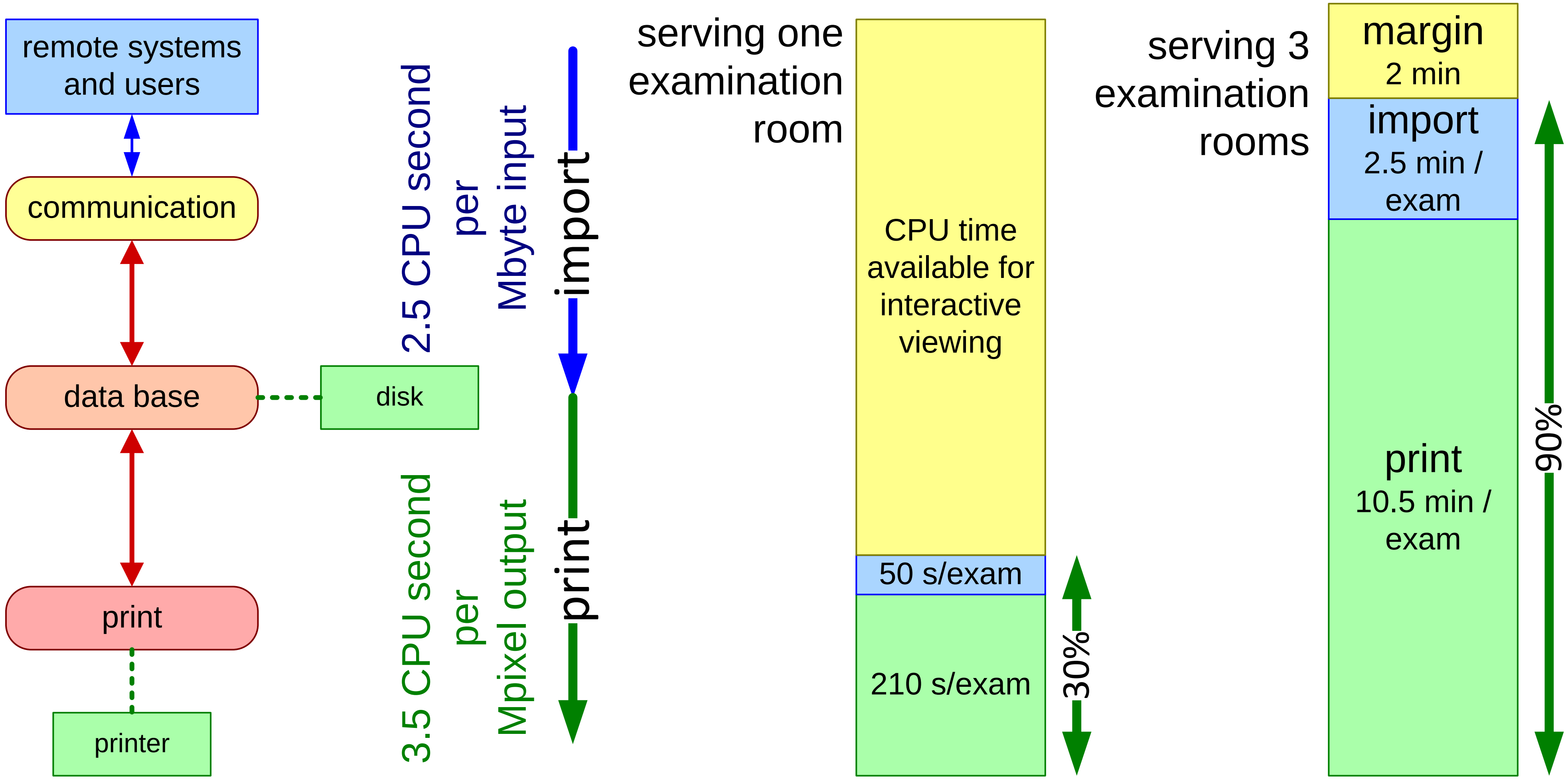
SW layers 1991



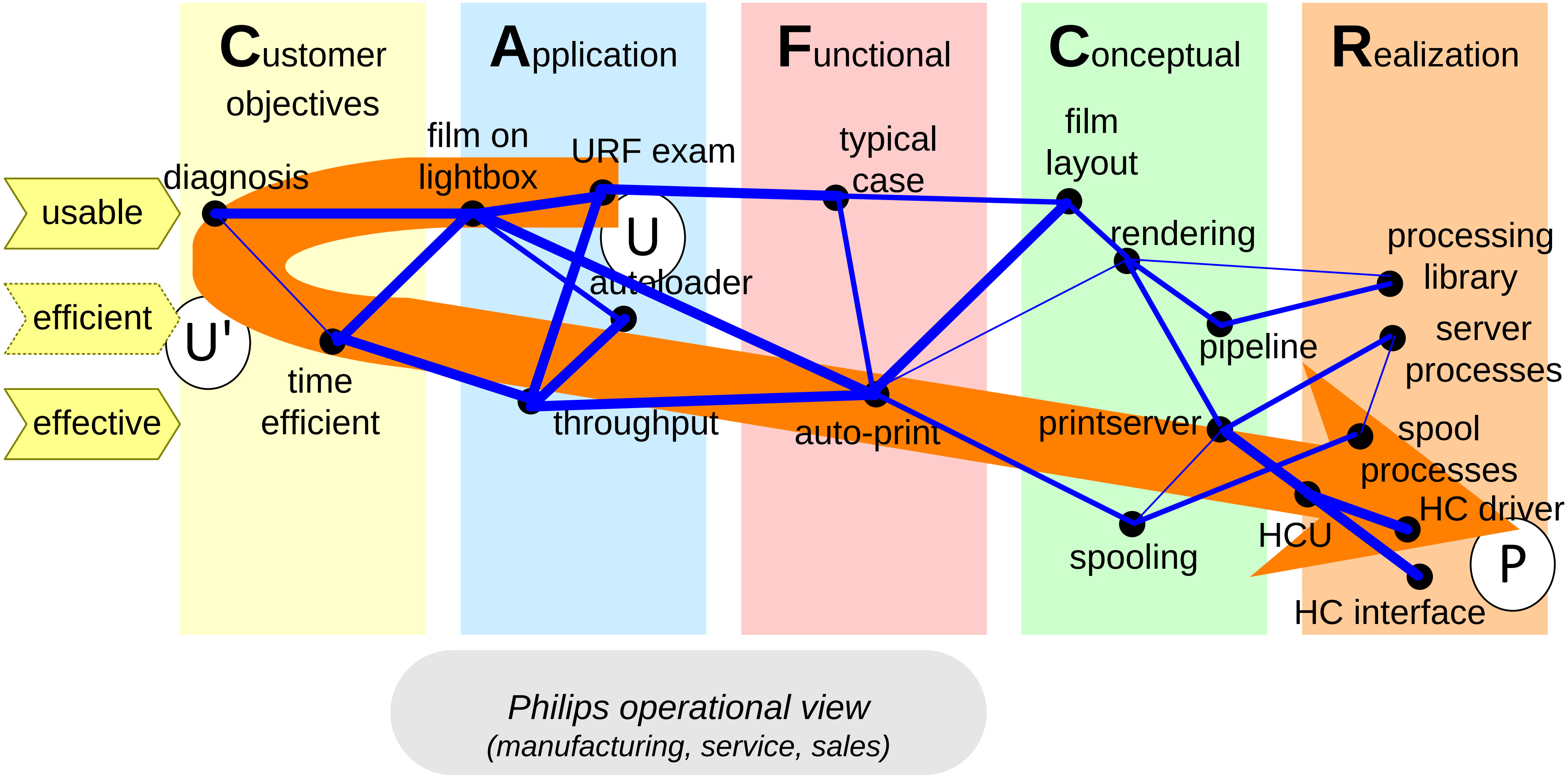
Print server is based on banding



Server CPU load

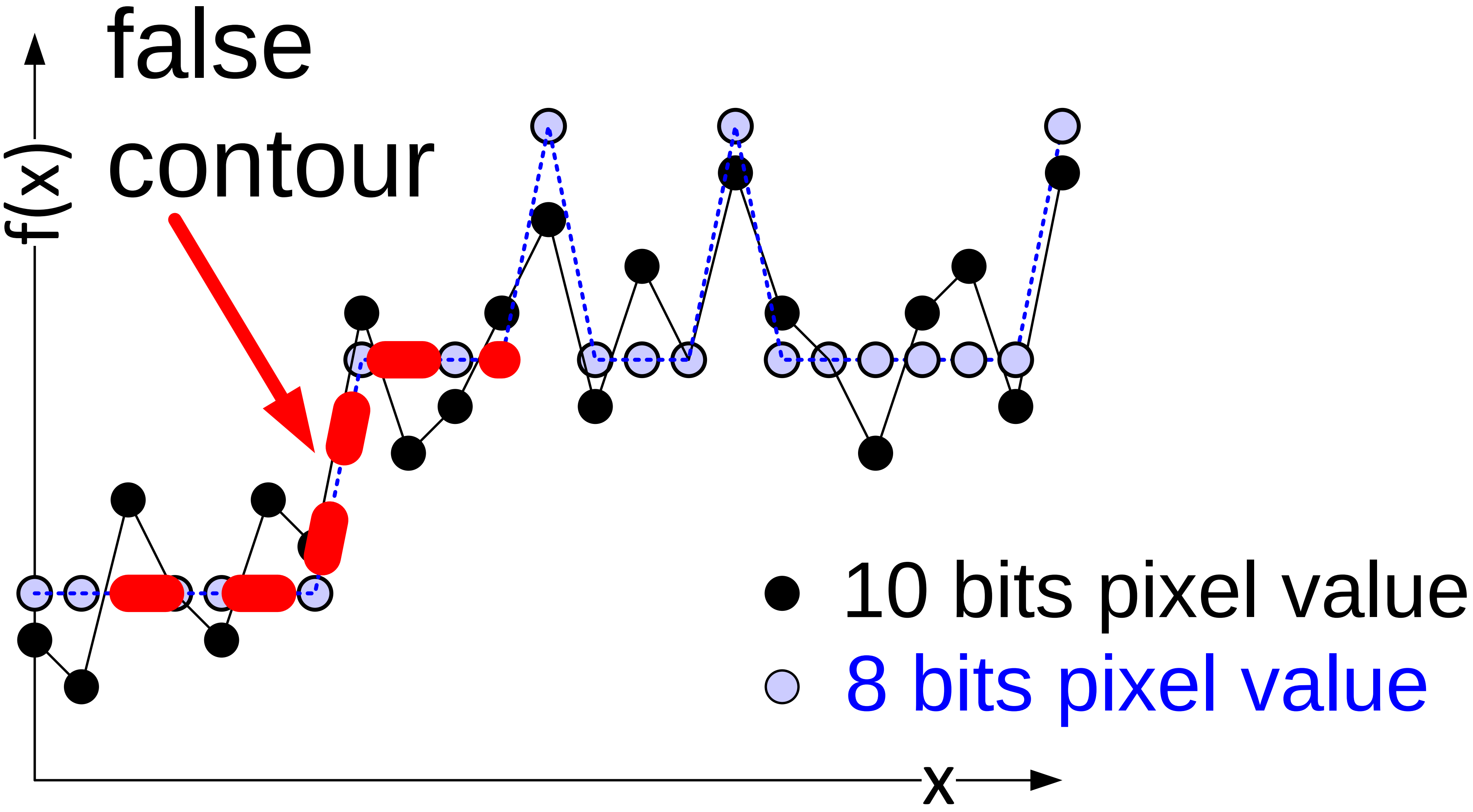


Thread of reasoning; phase 3



Radiologists diagnose from film, throughput is important
Extrovert view shows conceptual and realization gaps!

Image quality and safety problem



Presentation pipeline for X-ray images

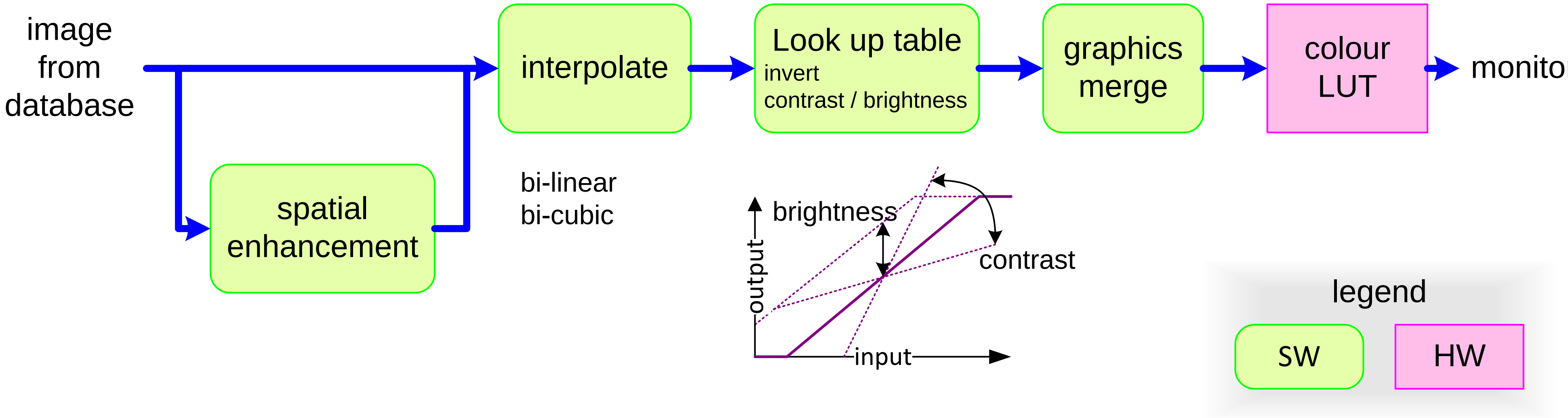
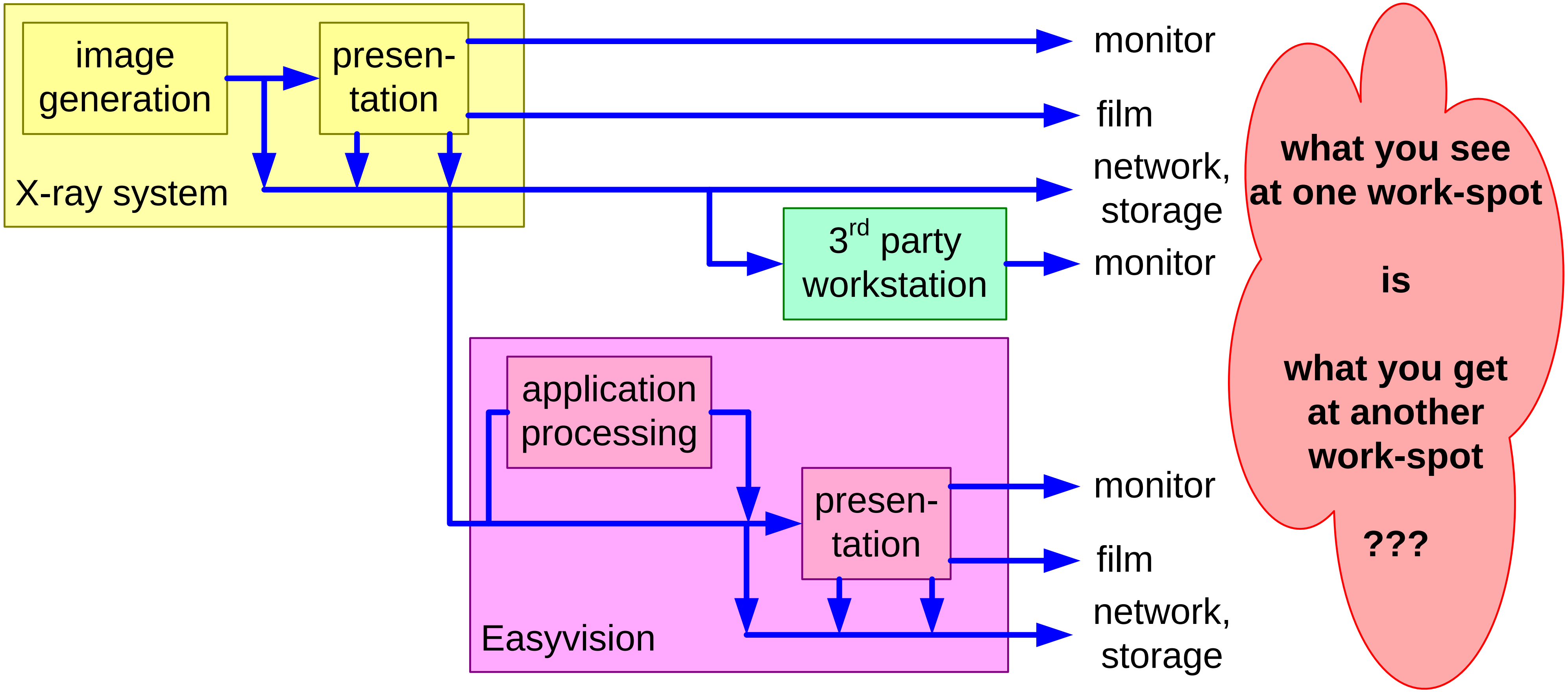
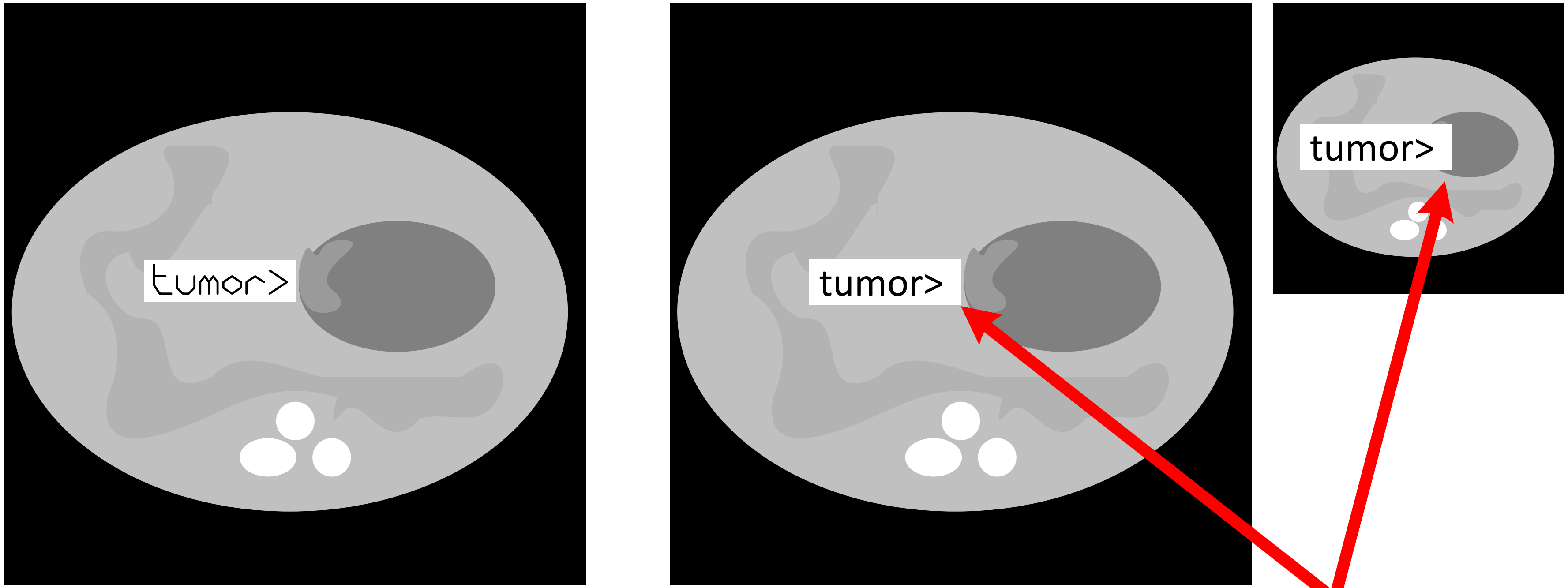


Image Quality expectation WYSIWYG



Safety problem

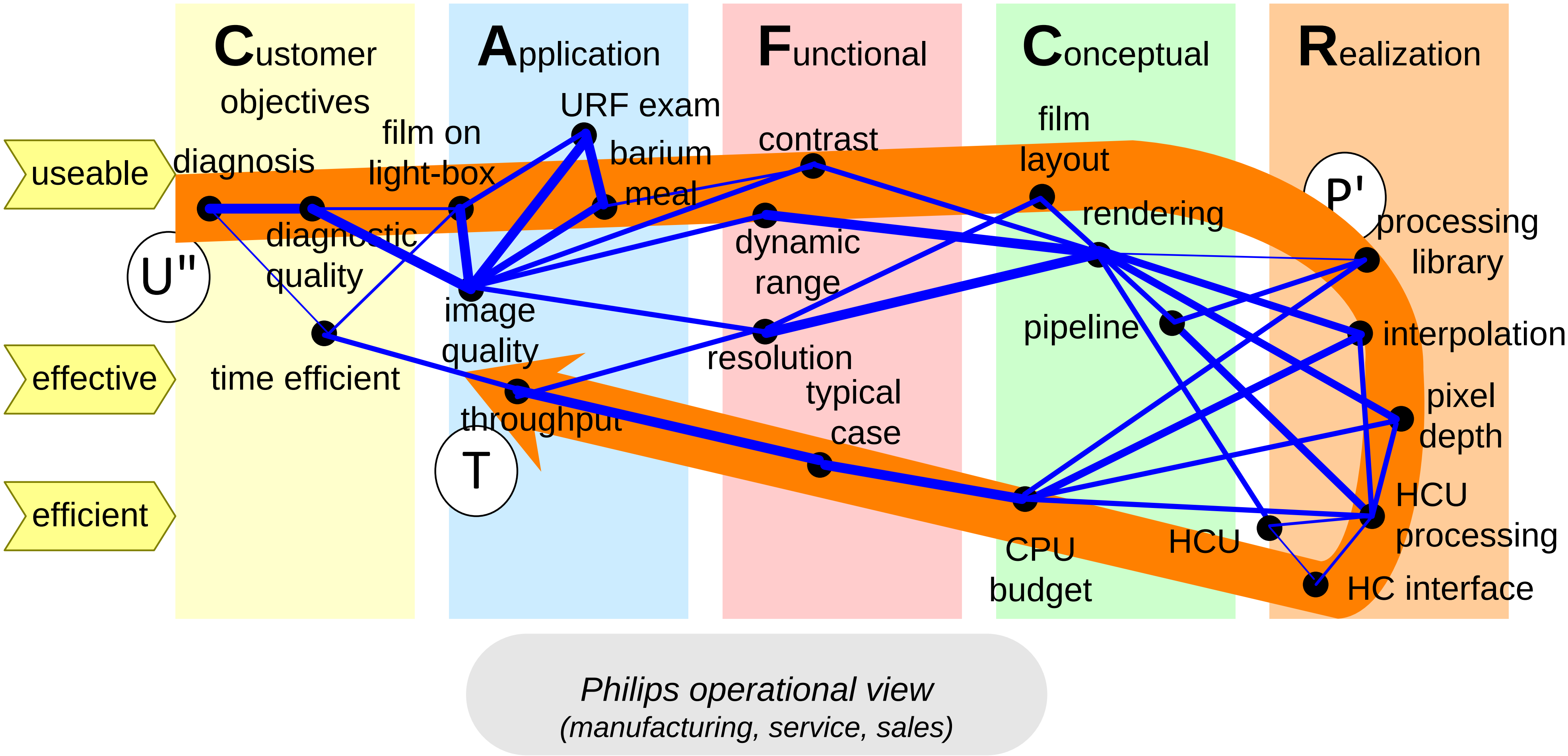


for user readability the font-size was determined "intelligently"; causing a dangerous mismatch between text and image

URF monitor output:
fixed size letters at fixed grid

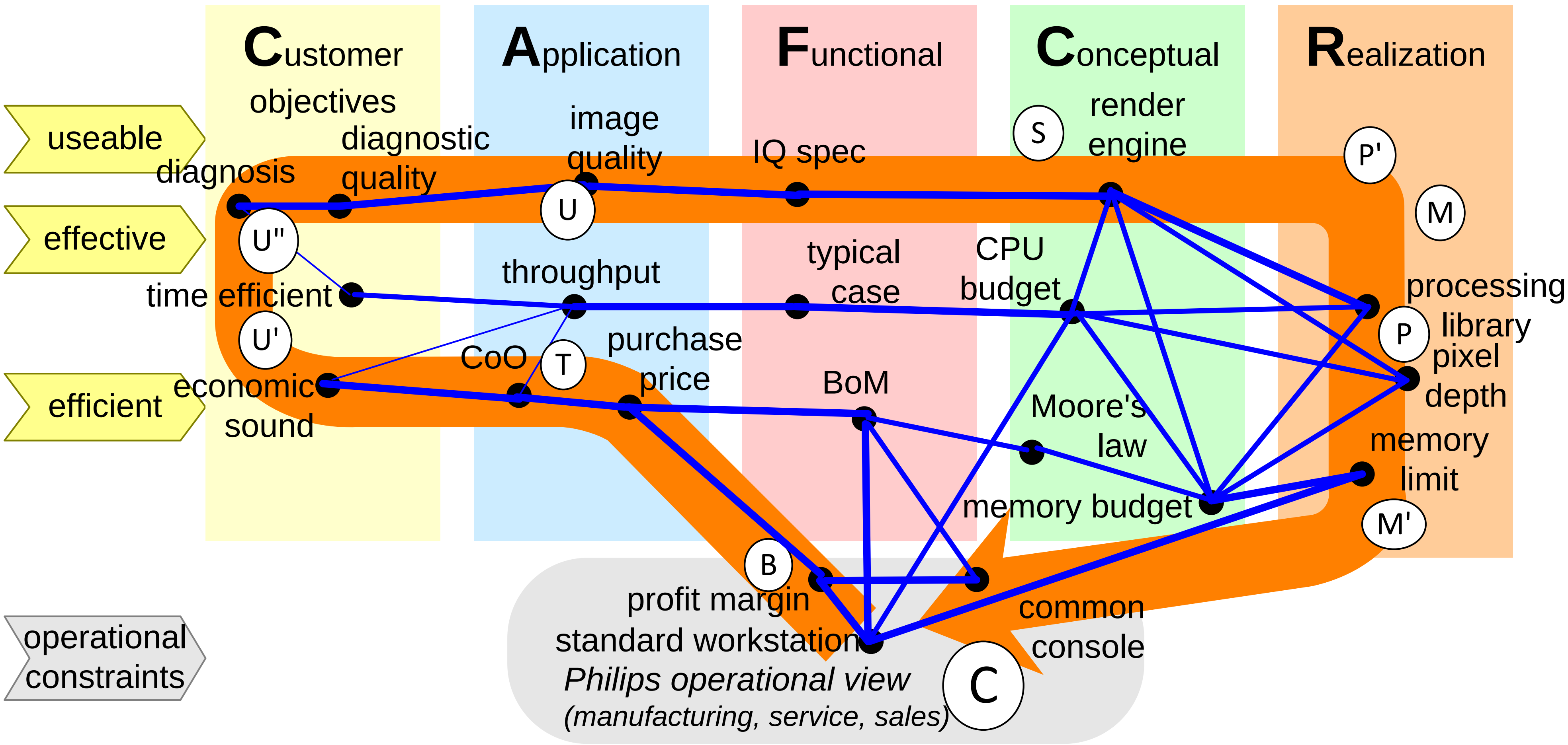
EV output: scaleable fonts in graphics overlay

Thread of reasoning; phase 4



from extrovert diagnostic quality, via image quality, algorithms and load, to extrovert throughput

Thread of reasoning; phase 5

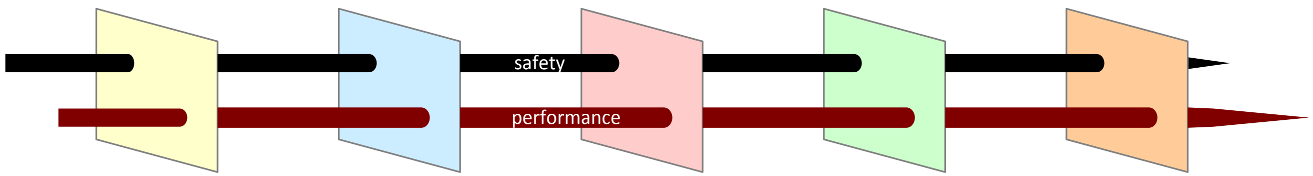


cost revisited in context of clinical needs and realization constraints; note: original threads are significantly simplified

Overview of architecting method

method outline	*method visualization*				
framework	**C**ustomer objectives	**A**pplication	**F**unctional	**C**onceptual	**R**ealization
submethods	+ key drivers + value chain + business models + supplier map	+ stakeholders and concerns + context diagram + entity relationship models + dynamic models	+ use case + commercial, logistics decompositions + mapping technical functions and several more	+ construction decomposition + functional decomposition + information model and many more	+ budget + benchmarking + performance analysis + safety analysis and many more

integration via qualities



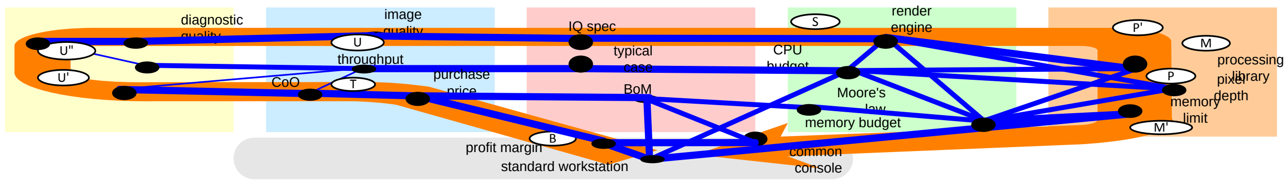
explore specific details

market vision

a priori solution know-how

story ⟷ analyse design ⟷ use case ⟷ analyse design ⟷ detailed design

reasoning



Exercise Threads of Reasoning

Customer objectives

Application

Functional

Conceptual

Realization

1 select
3..5 most important needs and concerns

2 select
3..5 most important specification issues

3 select
3..5 most critical design aspects

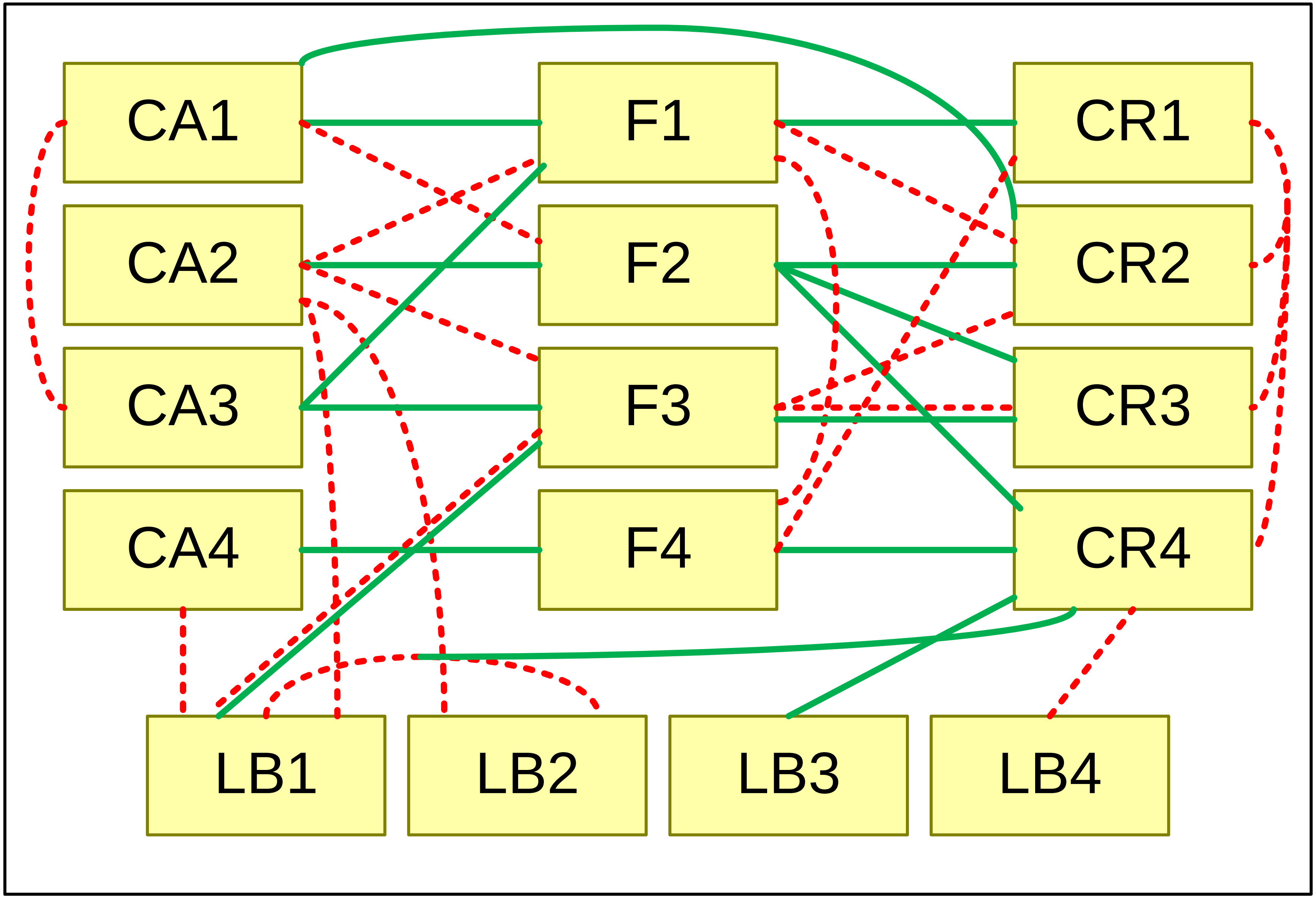
4 select
3..5 most critical life cycle and business issues

5 show relations
positive
negative

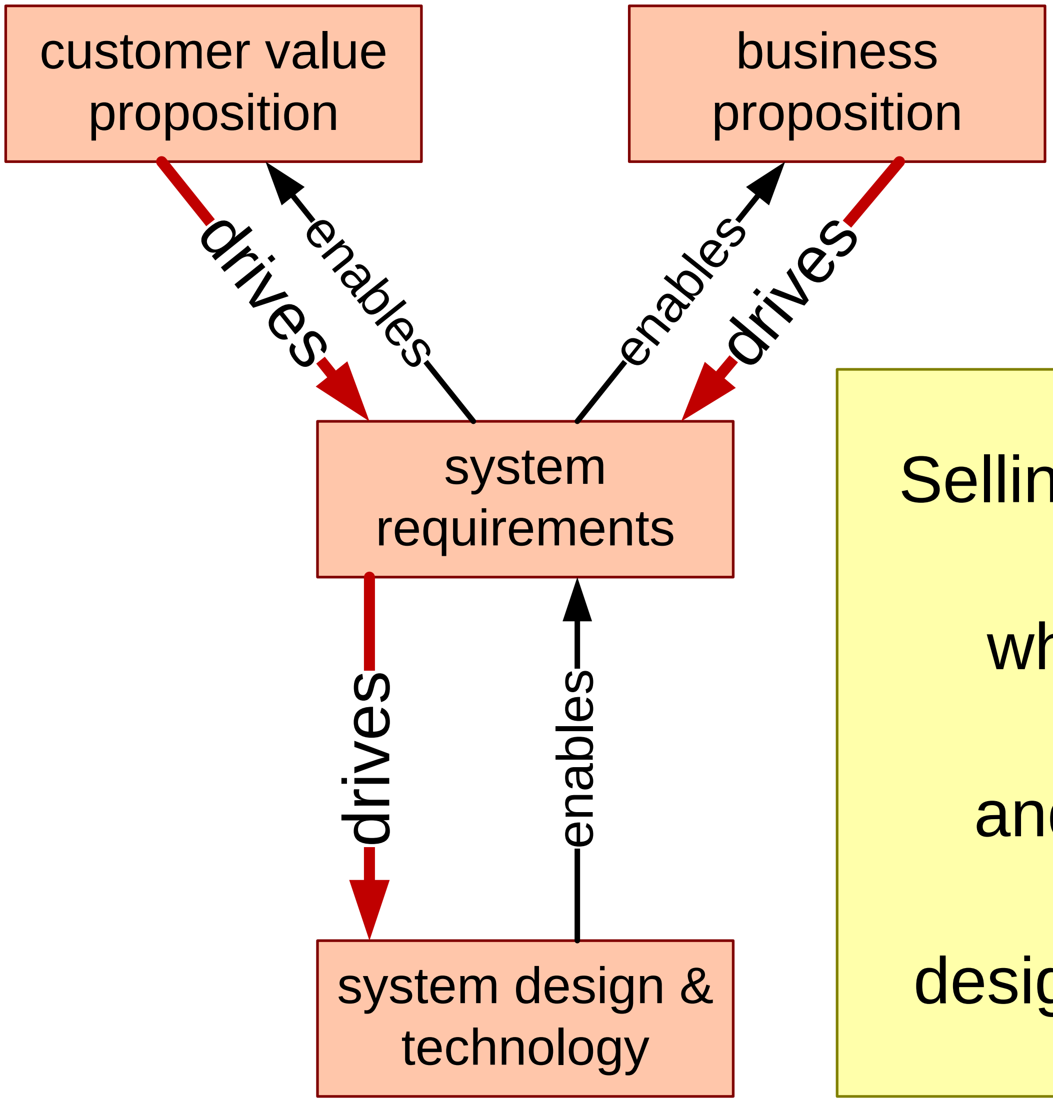
Life cycle and **B**usiness

6 transform into elevator pitch

“Spaghetti” after Step 5



Elevator Pitch of about 90 seconds



Selling and explaining the proposal

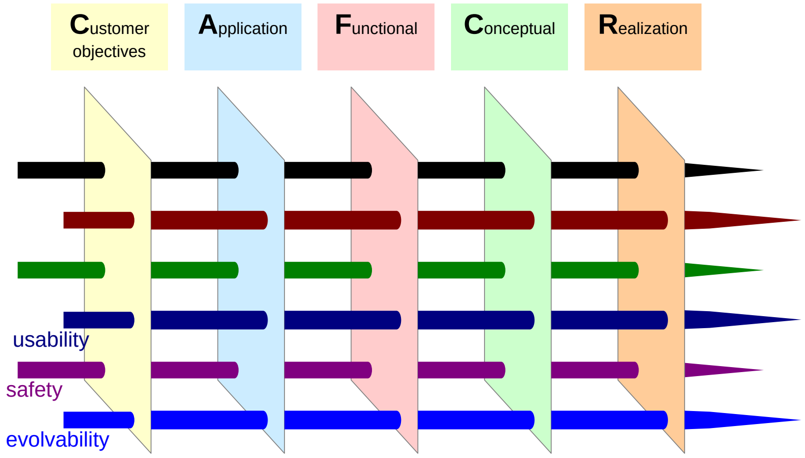
while managing expectations

and engaging management in

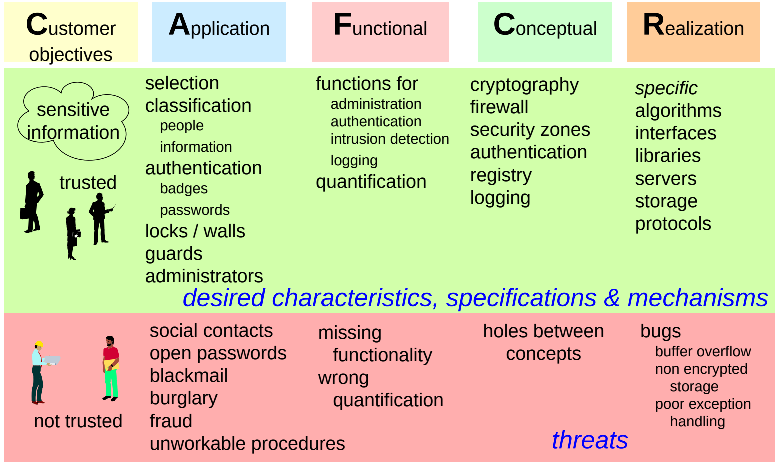
design and technology challenges

Integration via Qualities

Qualities Connect all Views



Look Positive and Negative



Many, Many Qualities

usable
- usability
- attractiveness
- responsiveness
- image quality
- wearability
- storability
- transportability

dependable
- safety
- security
- reliability
- robustness
- integrity
- availability

effective
- throughput or productivity

interoperable
- connectivity
- 3rd party extendible

liable
- liability
- testability
- traceability
- standards compliance

efficient
- resource utilization
- cost of ownership

consistent
- reproducibility
- predictability

serviceable
- serviceability
- configurability
- installability

future proof
- evolvability
- portability
- upgradeability
- extendibility
- maintainability

logistics friendly
- manufacturability
- logistics flexibility
- lead time

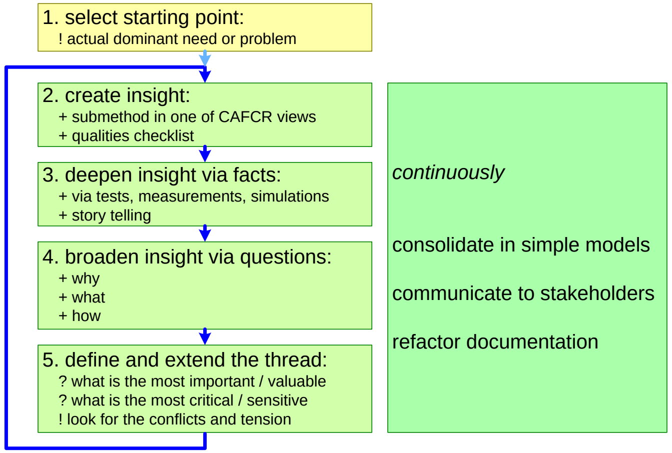
ecological
- ecological footprint
- contamination
- noise
- disposability

down to earth attributes
- cost price
- power consumption
- consumption rate (water, air, chemicals, et cetera)
- size, weight
- accuracy

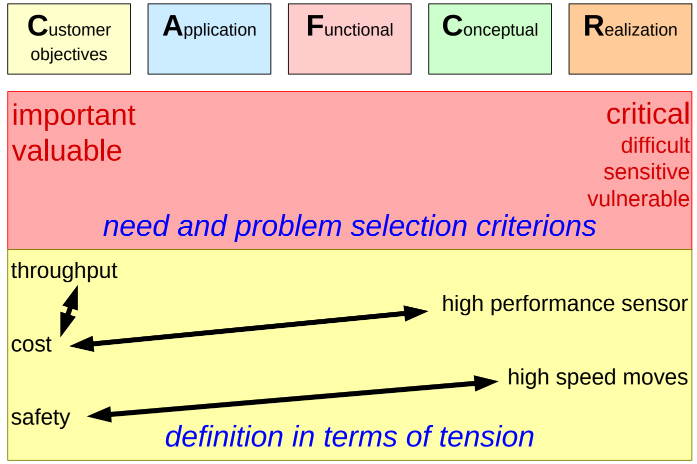
intentionally left blank

Threads of Reasoning

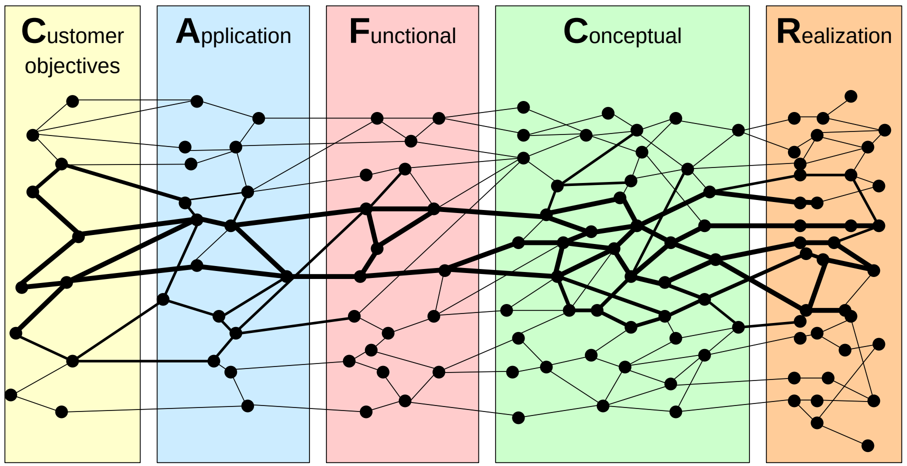
Diverge, Converge, Zoom-in, Zoom-out



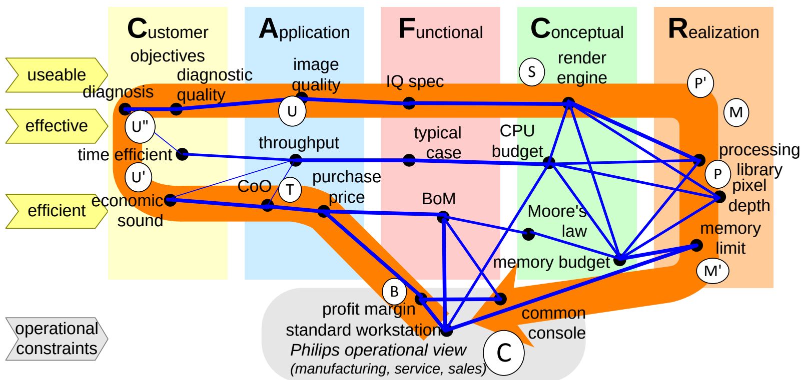
Identify Most Relevant Issues



All Issues are Interrelated



Reconstruct the "Big Picture"



cost revisited in context of clinical needs and realization constraints; note: original threads are significantly simplified

Module 38, Modeling

by *Gerrit Muller* University of South-Eastern Norway-NISE
e-mail: gaudisite@gmail.com
www.gaudisite.nl

Abstract

This module discusses modeling, especially aspects such as credibility, working range, and accuracy.

Distribution

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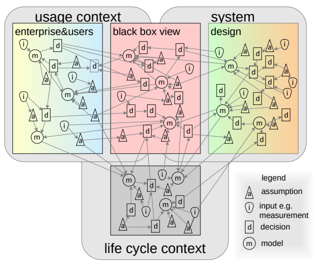
Modeling and Analysis: Reasoning Approach

by *Gerrit Muller* TNO-ESI, HSN-NISE
e-mail: gaudisite@gmail.com
www.gaudisite.nl

Abstract

We make models to facilitate decision making. These decisions range from business decisions, such as Service Level Agreements, to requirements, and to detailed design decisions. The space of decisions is huge and heterogeneous. The proposed modeling approach is to use multiple small and simple models. In this paper we discuss how to reason by means of multiple models.



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version: 1.0

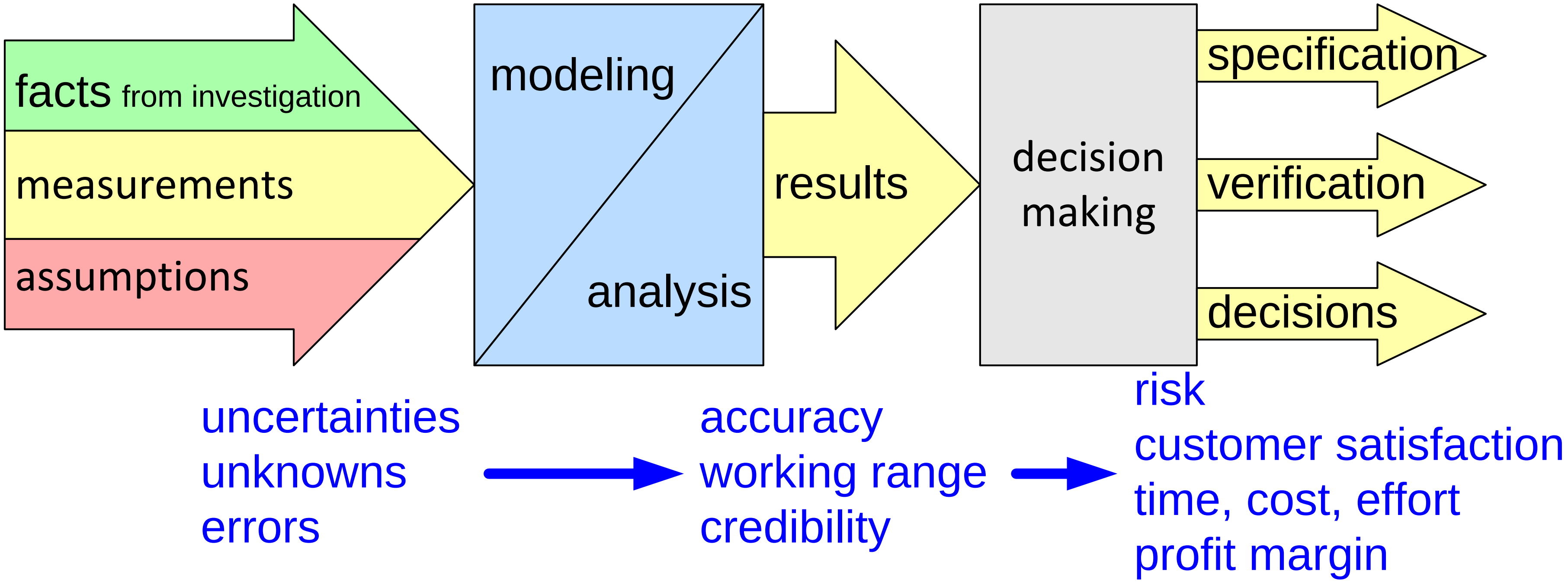
Purpose of Modeling

How to use multiple models to facilitate decisions?

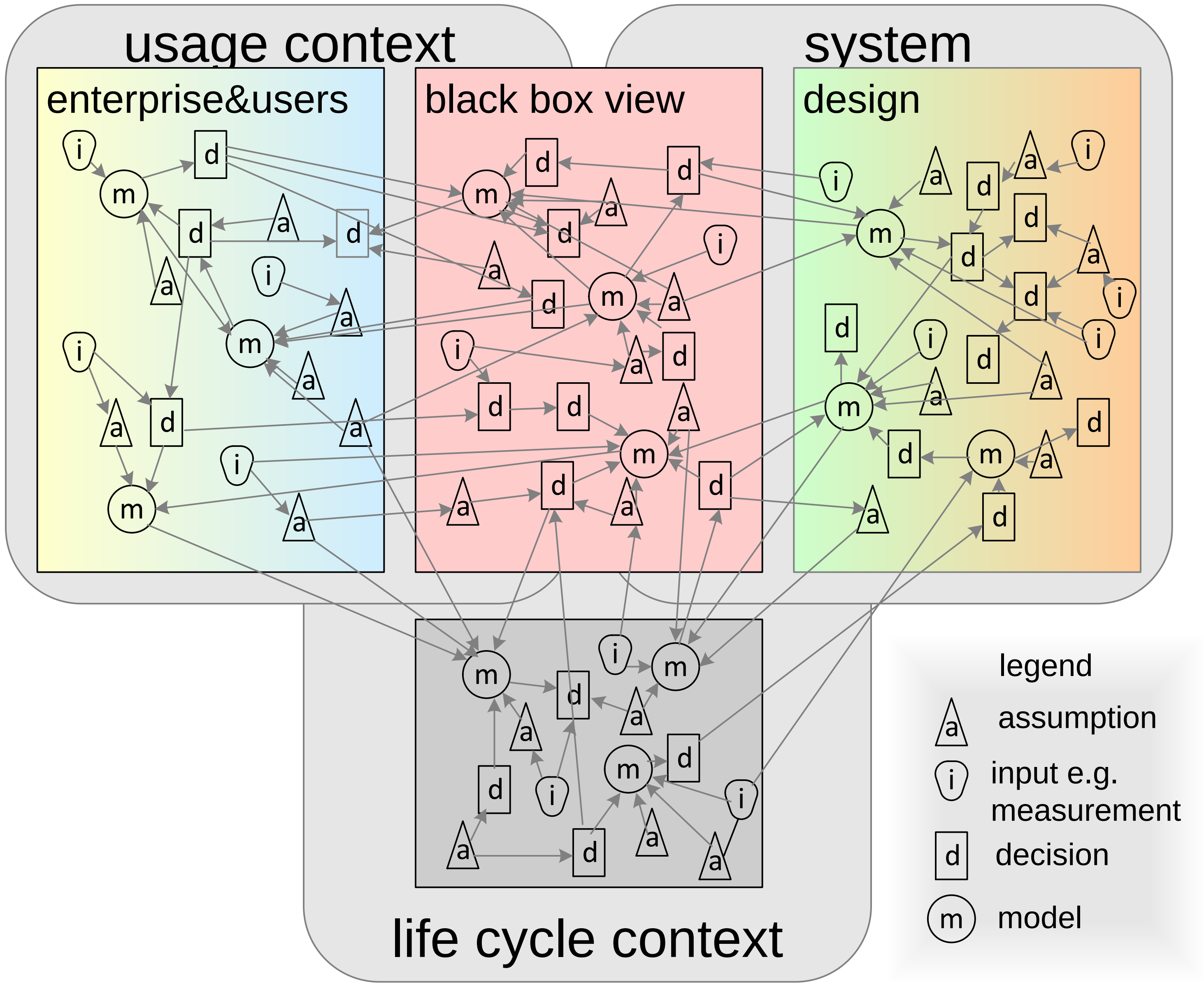
How to get from many fragments to integral insight?

How many models do we need?

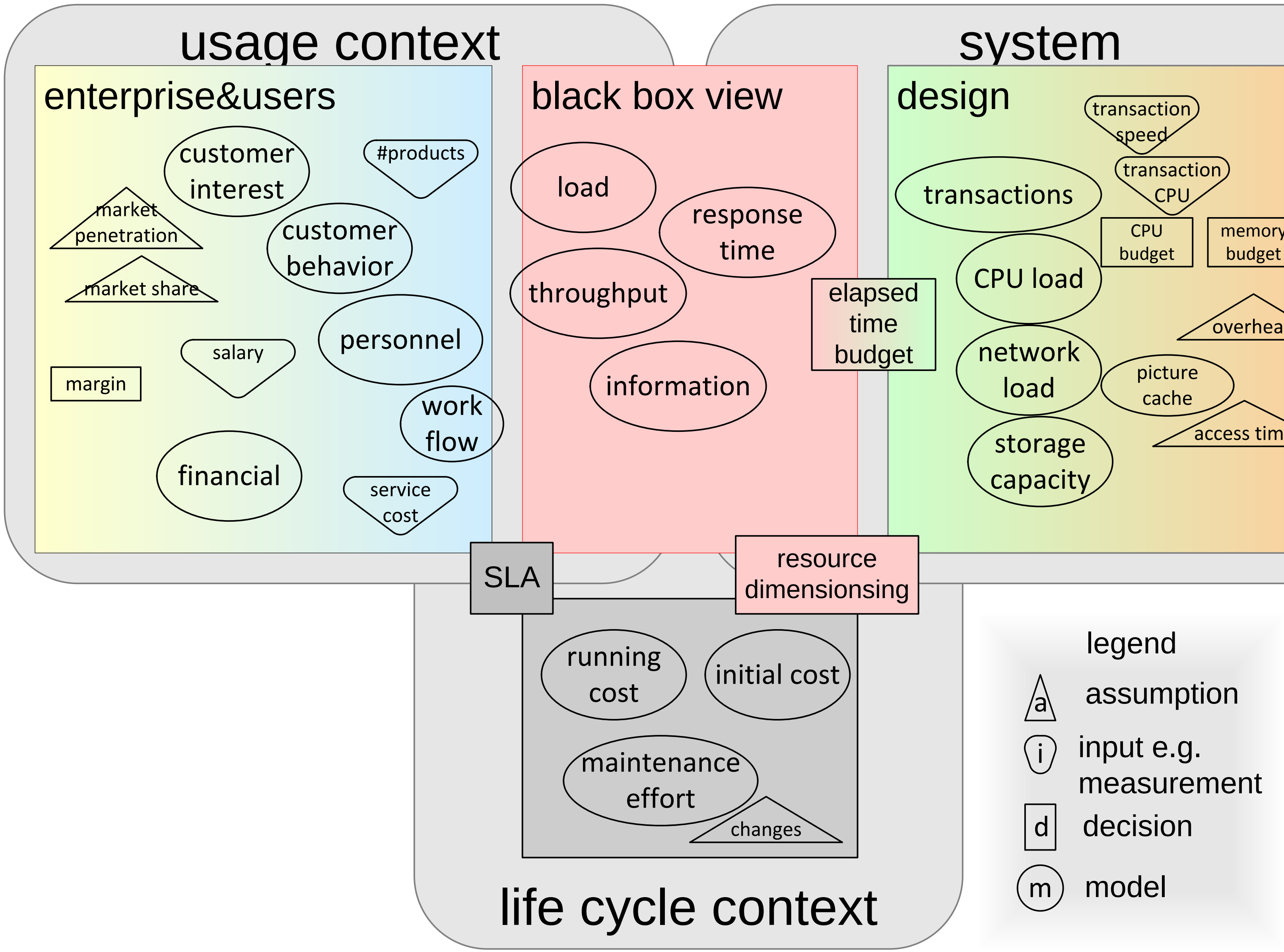
At what quality and complexity levels ?



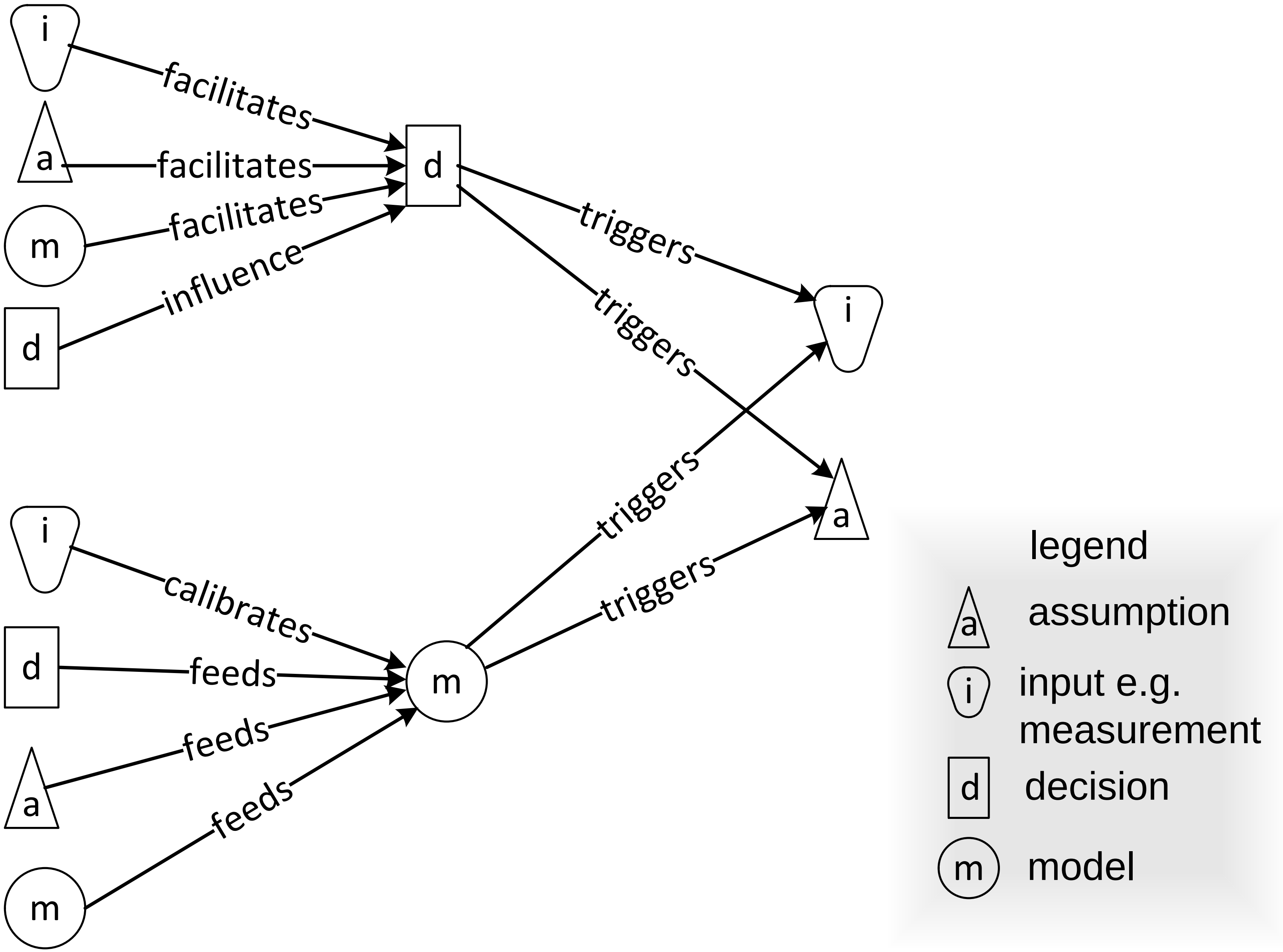
Graph of Decisions and Models



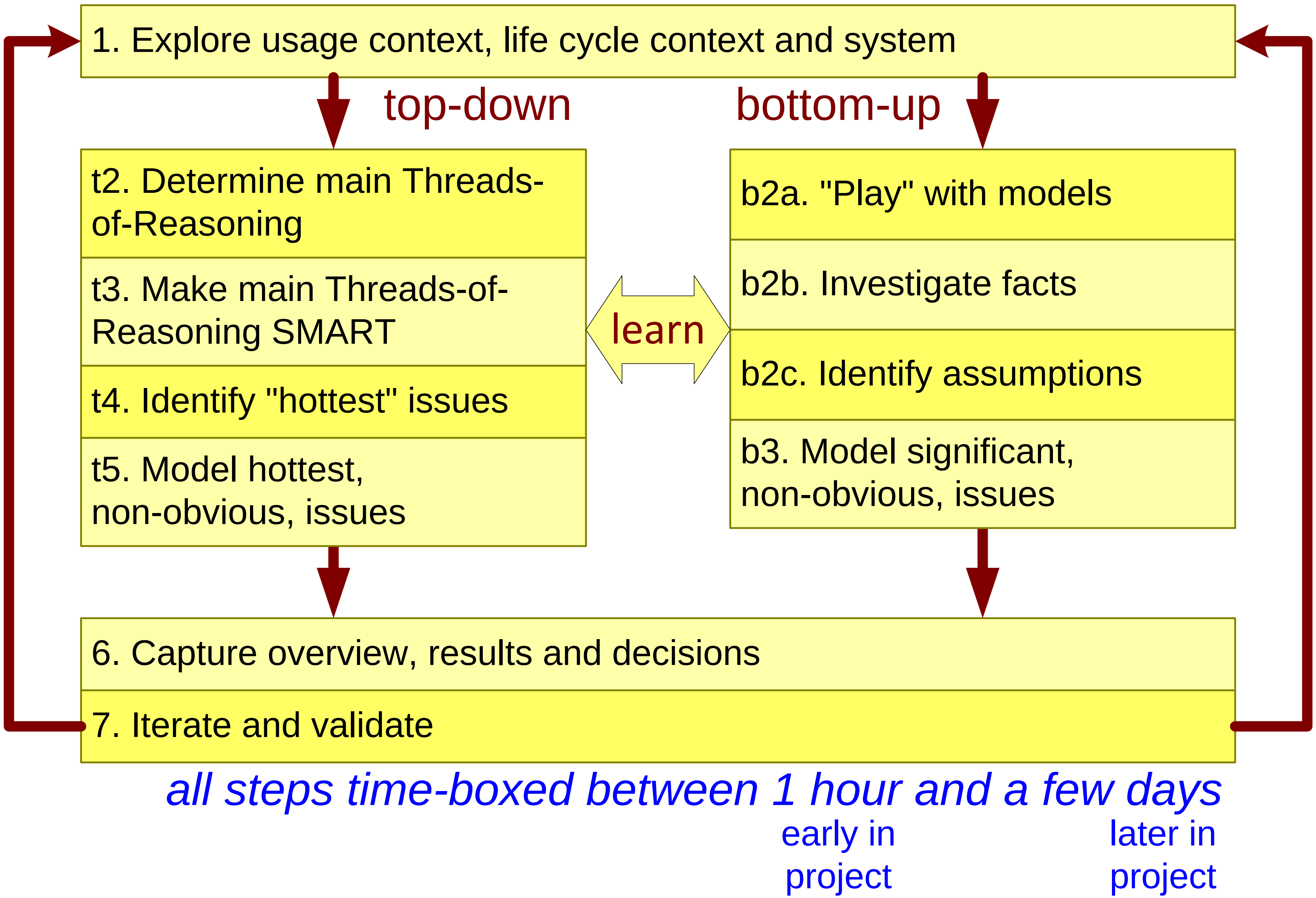
Example Graph for Web Shop



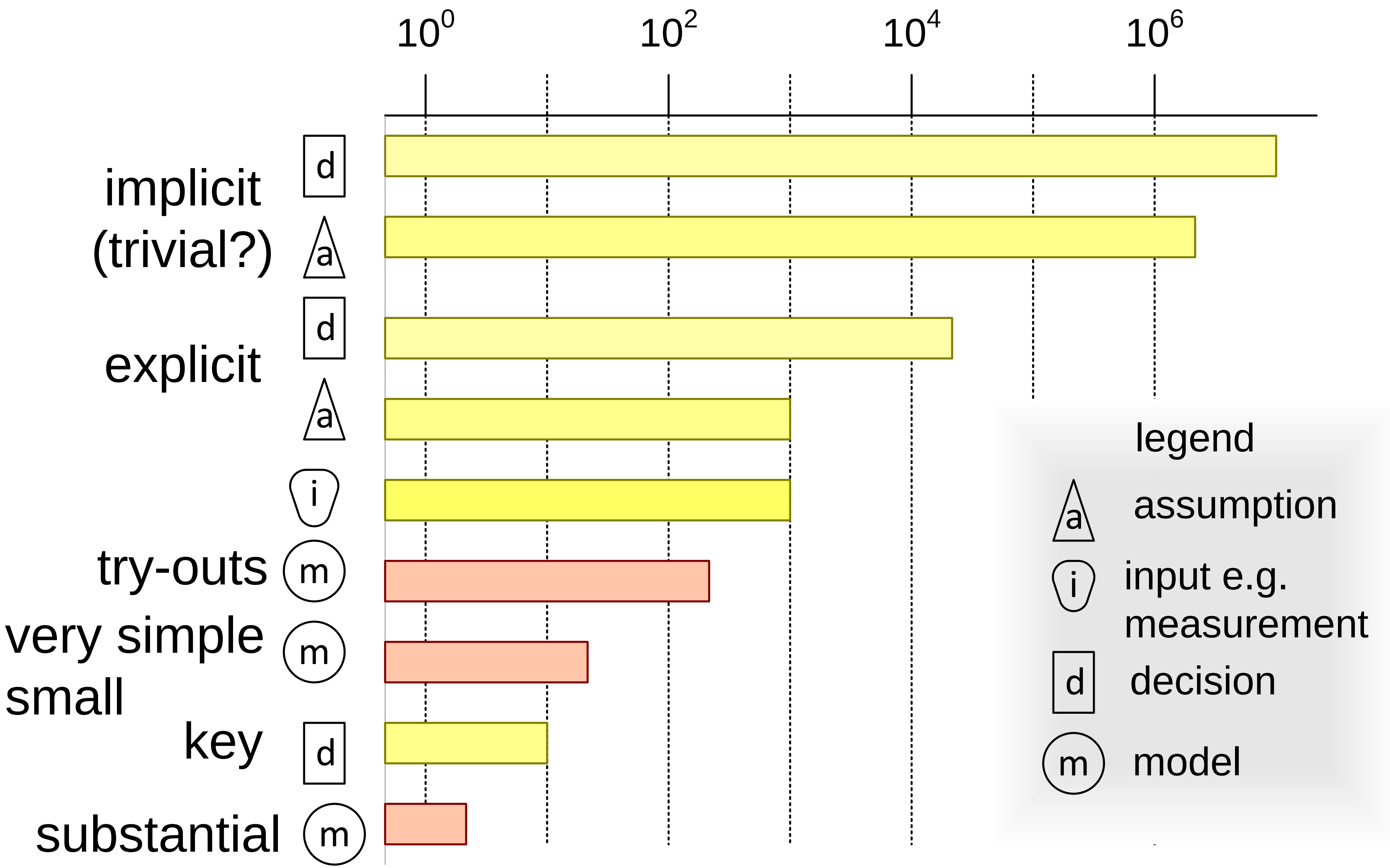
Relations: Decisions, Models, Inputs and Assumptions



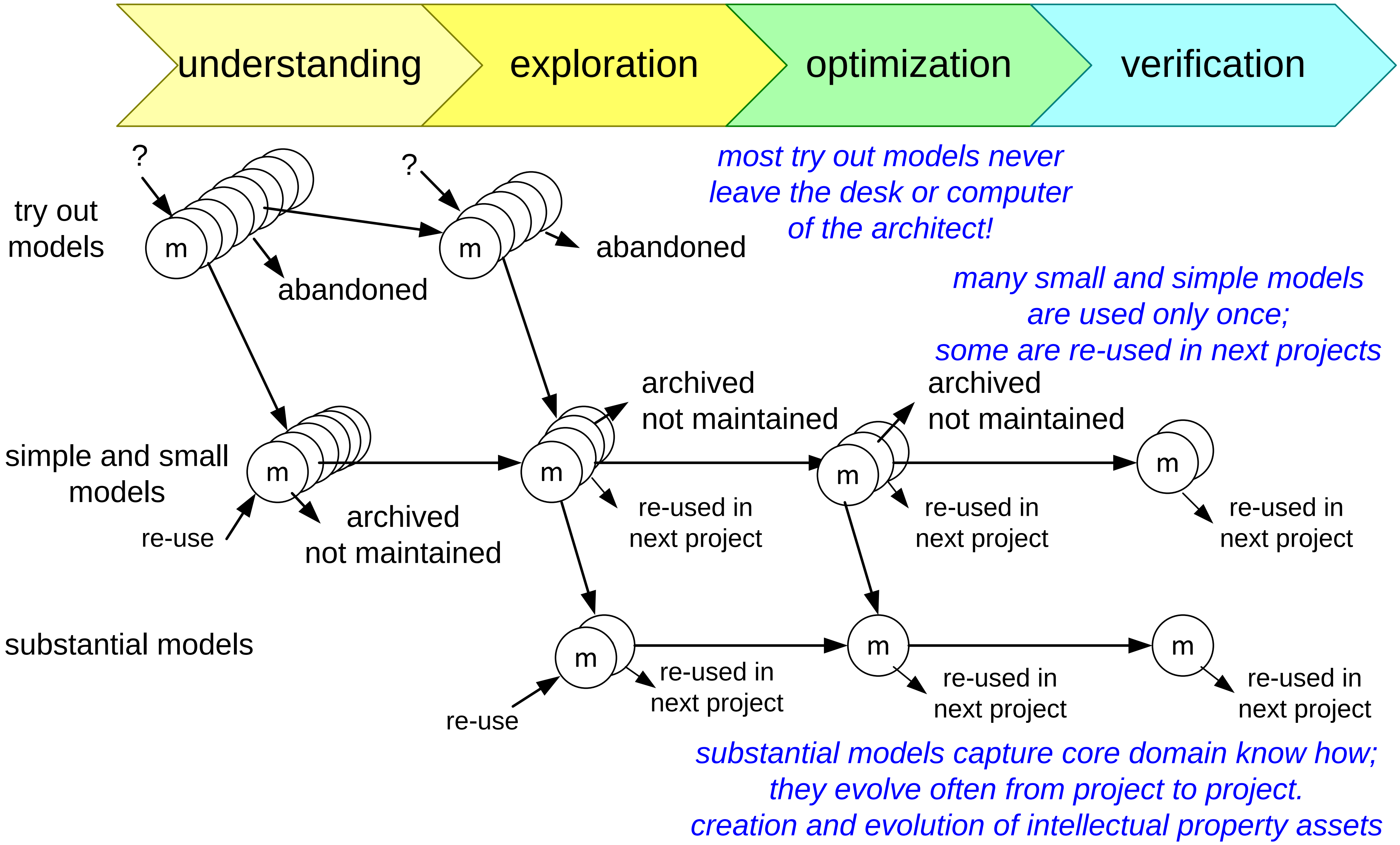
Reasoning Approach



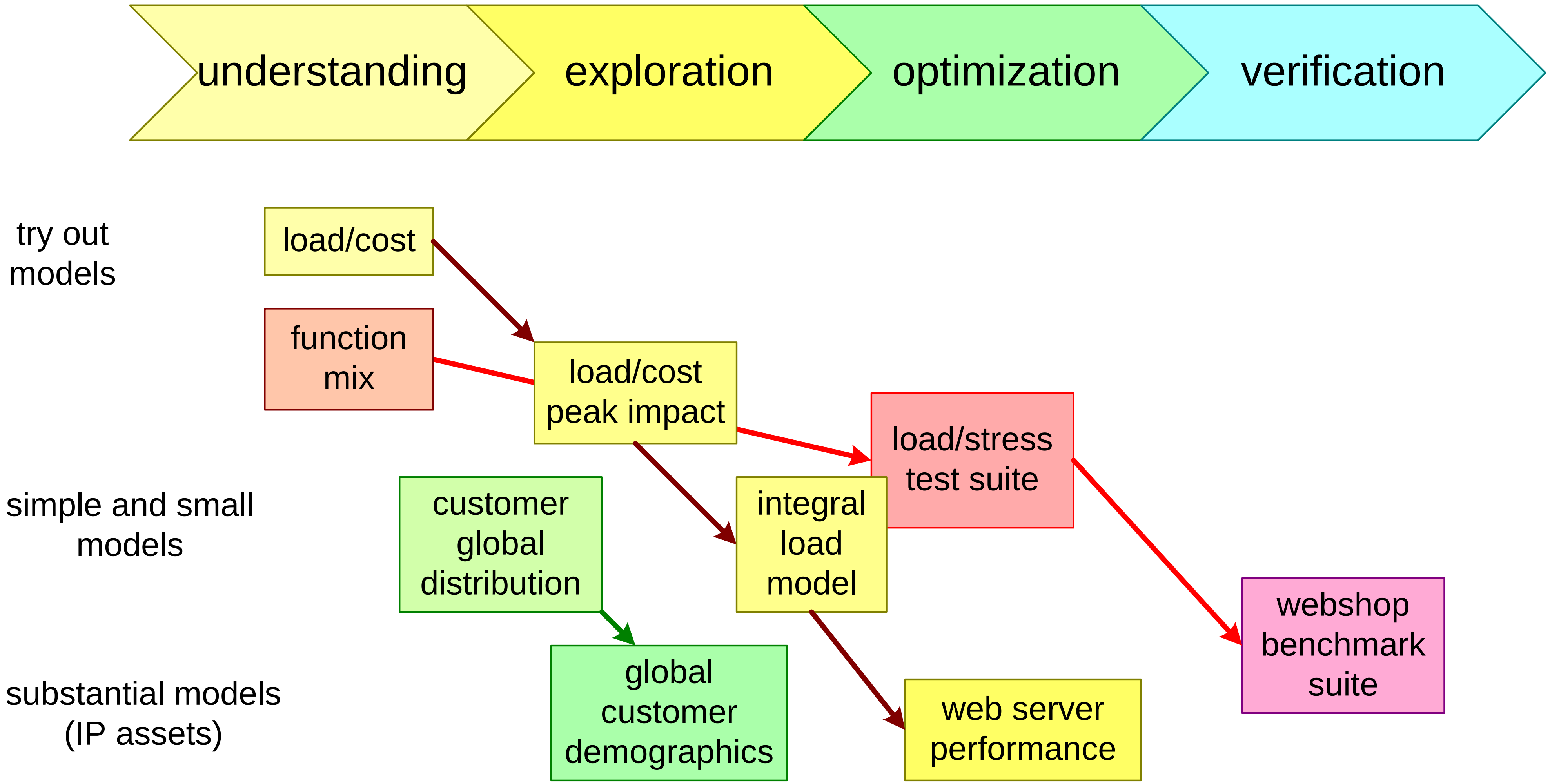
Frequency of Assumptions, Decisions and Modeling



Life Cycle of Models



Examples of Life Cycle of Models



Exercise Chain of Models

Identify a **chain of models** needed to support architecture development.

- models are related horizontally in the CAFCR model (across views), as well as vertically within a view
- models have various levels of detail; detailed models tend to feed/ support less detailed models
- per model
  - formulate its purpose
  - indicate the main quantities that play a role

Modeling and Analysis: Model Analysis

by *Gerrit Muller*   TNO-ESI, USN-NISE
e-mail: gaudisite@gmail.com
www.gaudisite.nl

Abstract

Models only get value when they are actively used. We will focus in this presentation on analysis aspects: accuracy, credibility, sensitivity, efficiency, robustness, reliability and scalability.

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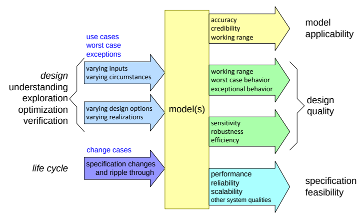
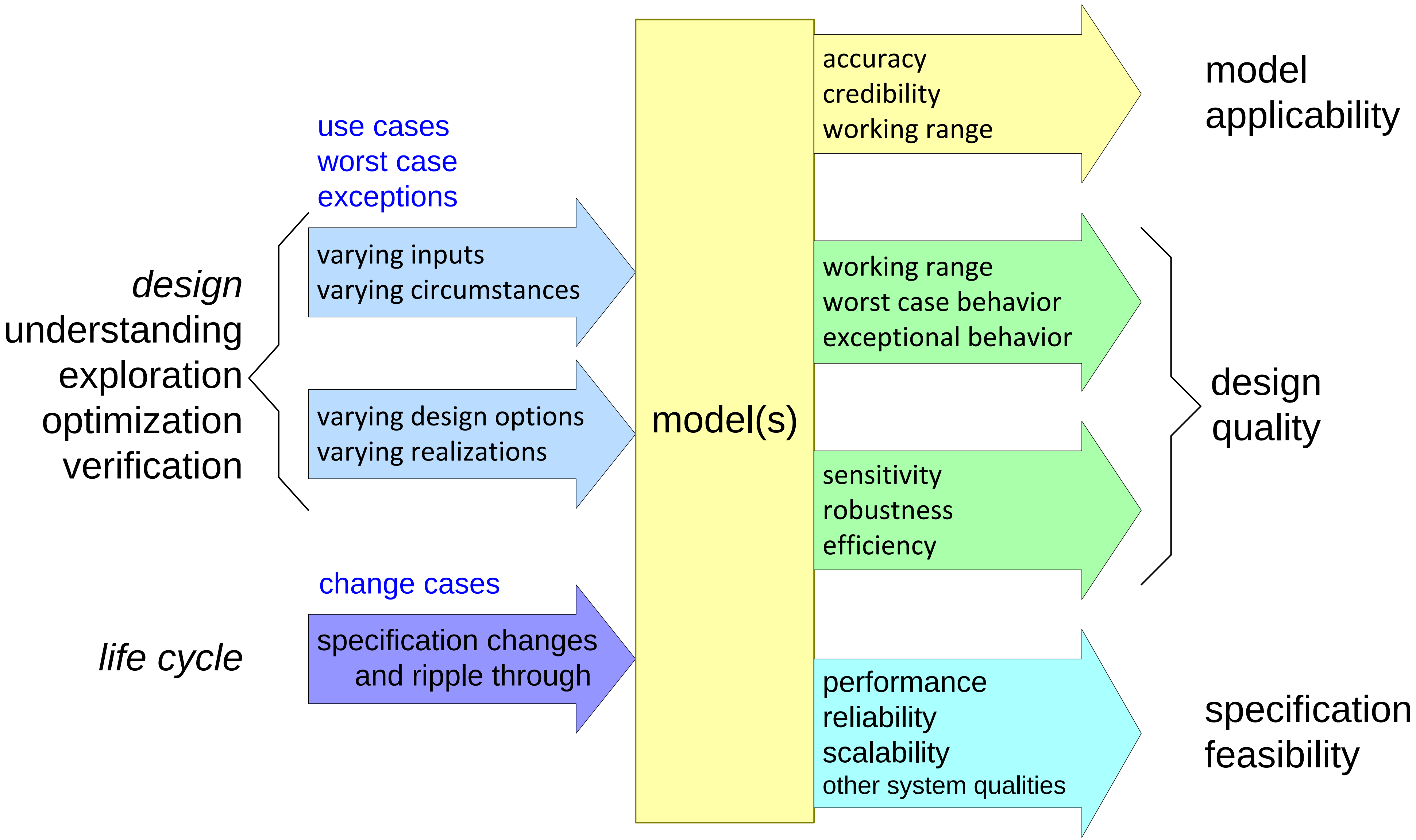
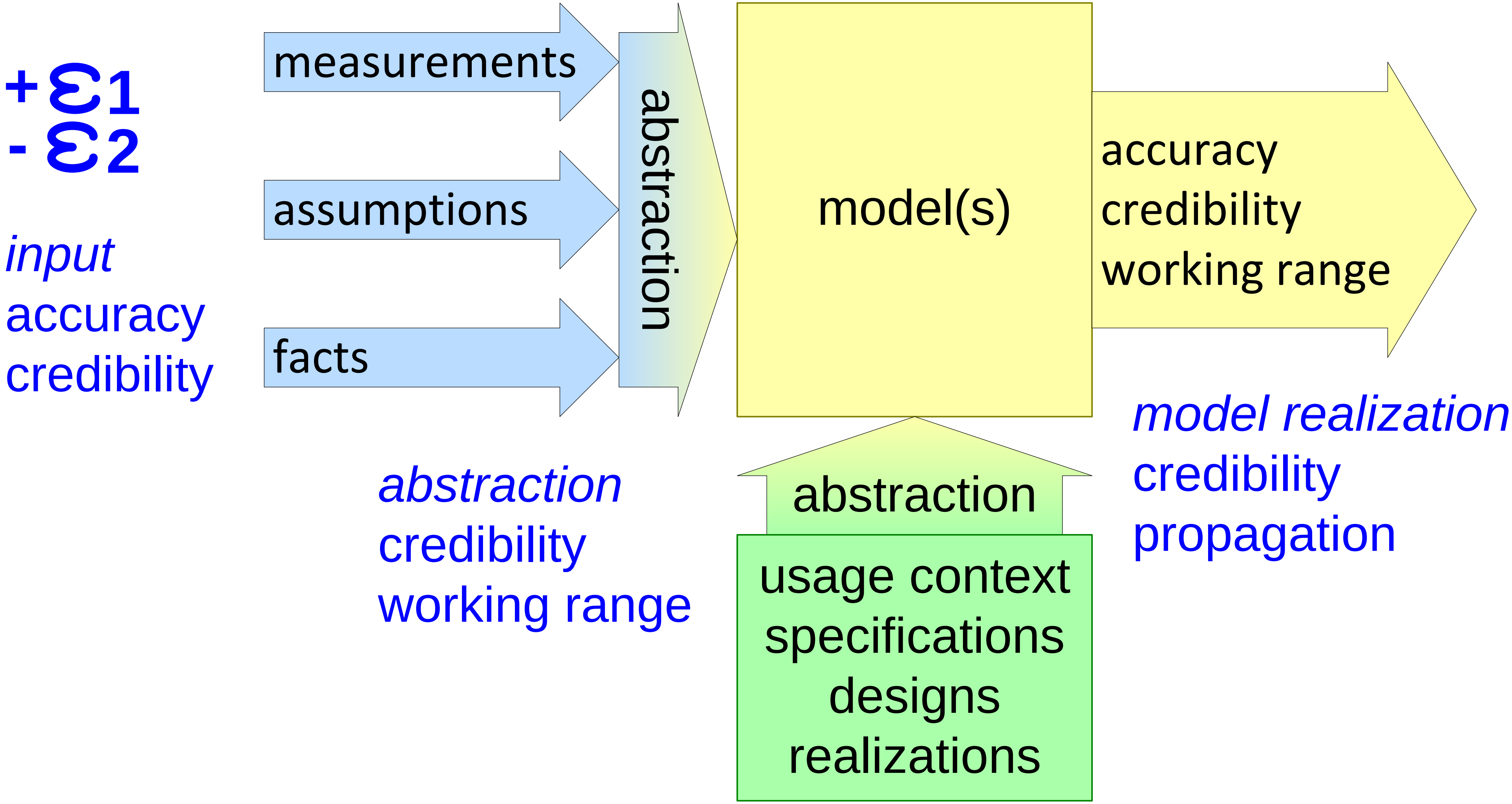


What Comes out of a Model



Applicability of the Model



How to Determine Applicability

try out models

be aware of accuracy, credibility and working range

simple and small models

1. Estimate accuracy of results

   based on most significant inaccuracies of inputs and assumed model propagation behavior

2. Identify top 3 credibility risks

   identify biggest uncertainties in inputs, abstractions and realization

3. Identify relevant working range risks

   identify required (critical) working ranges and compare with model working range

substantial models

systematic analysis and documentation of accuracy, credibility and working range

Common Pitfalls

discrete events in continuous world

discretization artefacts
e.g. stepwise simulations

(too) systematic input data

random data show different behavior
e.g. memory fragmentation

fragile model

small model change results in large shift in results

self fulfilling prophecy

price erosions + cost increase (inflation) -> bankruptcy

Worst Case Questions

Which design assumptions have a big impact on system performance?

What are the worst cases for these assumptions?

How does the system behave in the worst case?

a. poor performance within spec

b. poor performance not within spec

c. failure -> reliability issue

FMEA-like Analysis Techniques

	(systematic) brainstorm	analysis and assessment probability severity propagation	improve spec, design, process, procedure, ...
safety hazard analysis	potential hazards	damage	measures
reliability FMEA	failure modes exceptional cases	effects	measures
security	vulnerability risks	consequences	measures
maintainability	change cases	impact, effort, time	decisions
performance	worst cases	system behavior	decisions

Brainstorming Phases

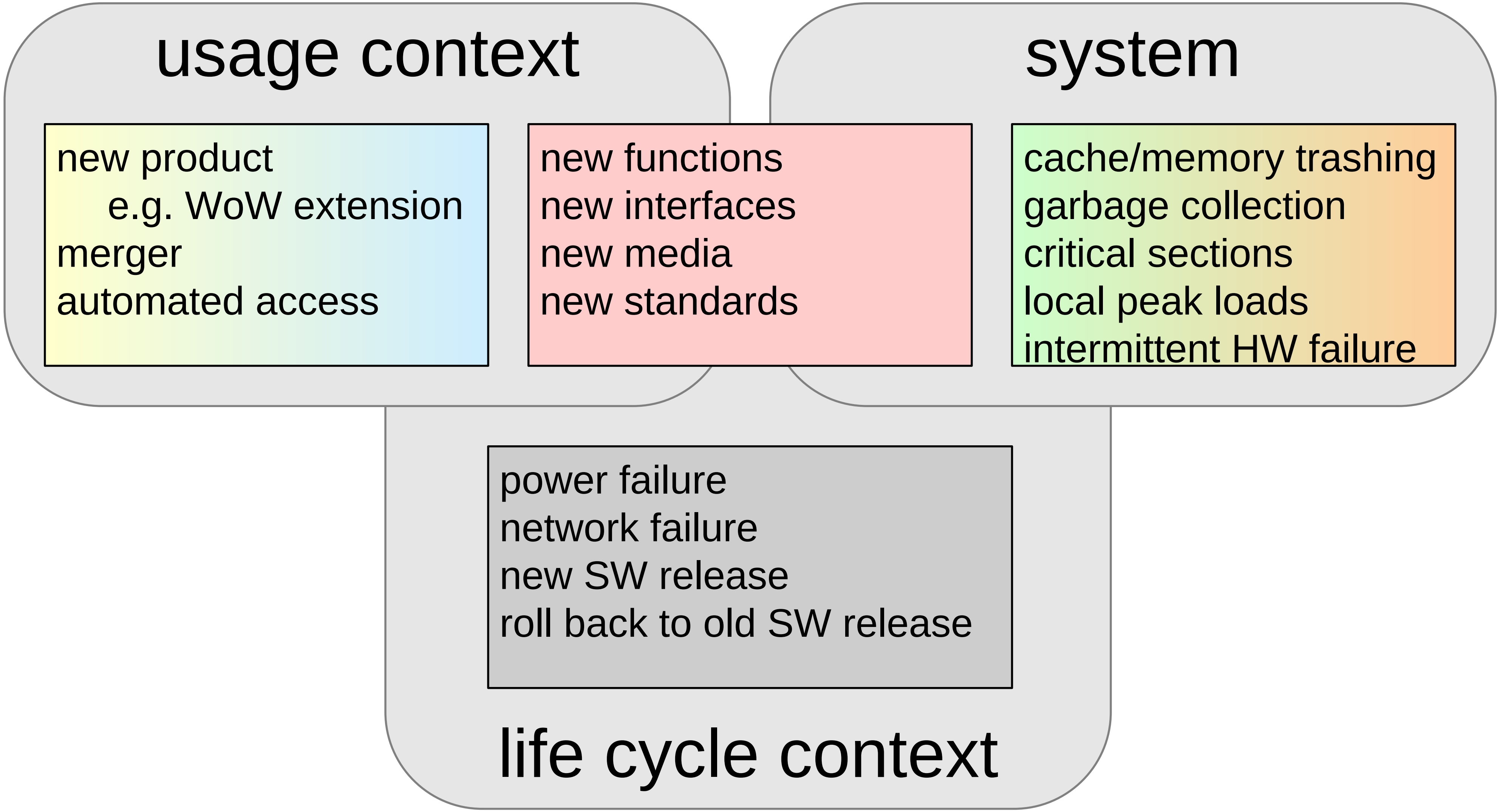
wave 1: the obvious

wave 2: more of the same

wave 3: the exotic, but potentially important

don't stop too early with brainstorming!

Different Viewpoints for Analysis



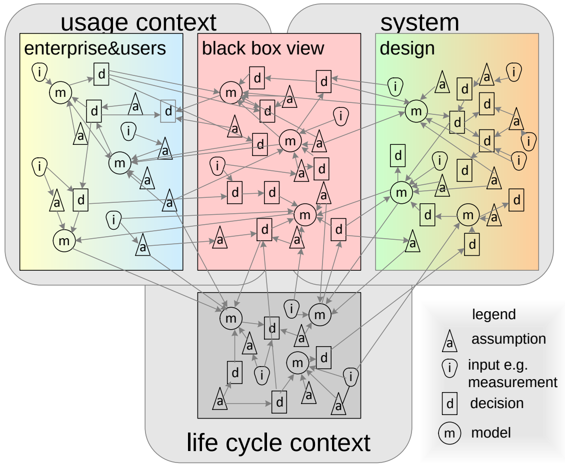
Exercise Analysis of Models

Determine for a few models their **credibility**, **accuracy**, and **working range**.

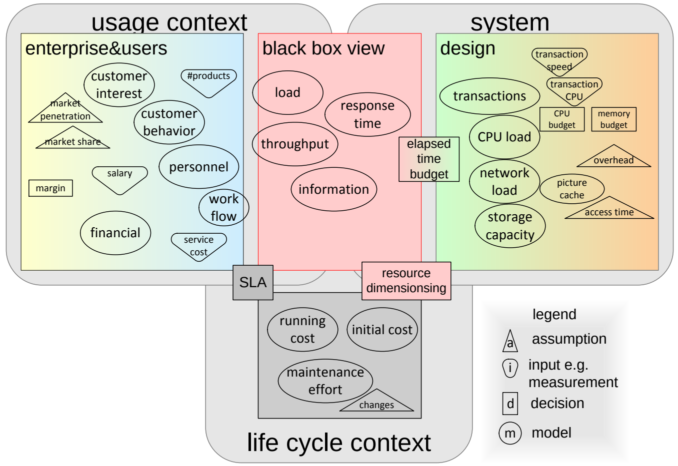
- Identify top 3 credibility risks
  - identify biggest uncertainties in inputs, abstractions and realization
- Estimate accuracy of results; quantitative, e.g. order 1% or 50%
  - based on most significant inaccuracies of inputs and assumed model propagation behavior
- Identify relevant working range risks
  - identify required (critical) working ranges and compare with model working range

Modeling

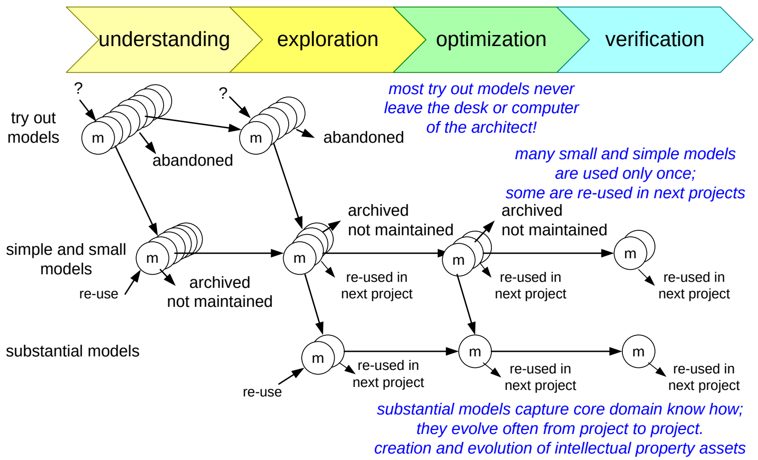
From Chaos...



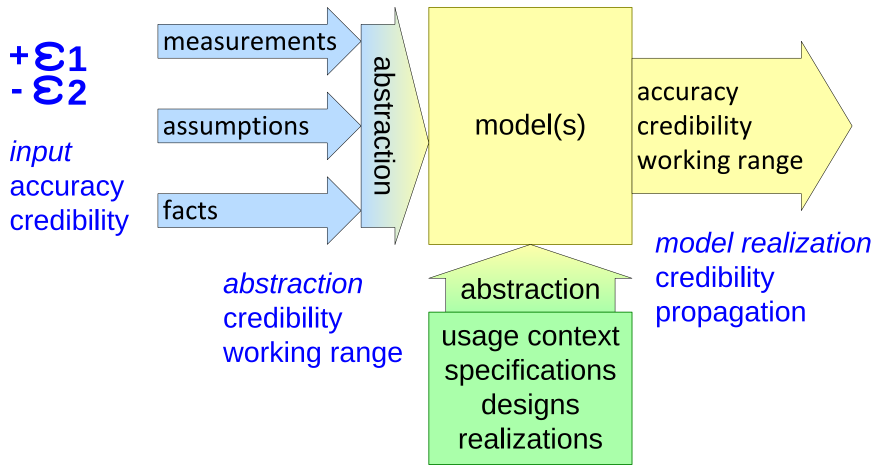
... to some Order



Many Light Models, few Substantial Models



Accuracy, Credibility, Working Range



Module 39, Wrap-up

by *Gerrit Muller* University of South-Eastern Norway-NISE
e-mail: gaudisite@gmail.com
www.gaudisite.nl

Abstract

This module provides various means to consolidate architectures.

Distribution

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Consolidating Architecture Overviews

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

e-mail: gaudisite@gmail.com

www.gaudisite.nl

Abstract

This presentation provides guidelines and means to capture architecture overviews. Main challenge is to maintain the overview across multiple views. Architecture Overview A3s One support multi-view. Another challenge is to make an overview accessible for a wide range of stakeholders. The architecture description should therefor be visualized such that it fits the mental model of the audience.

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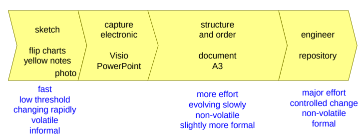
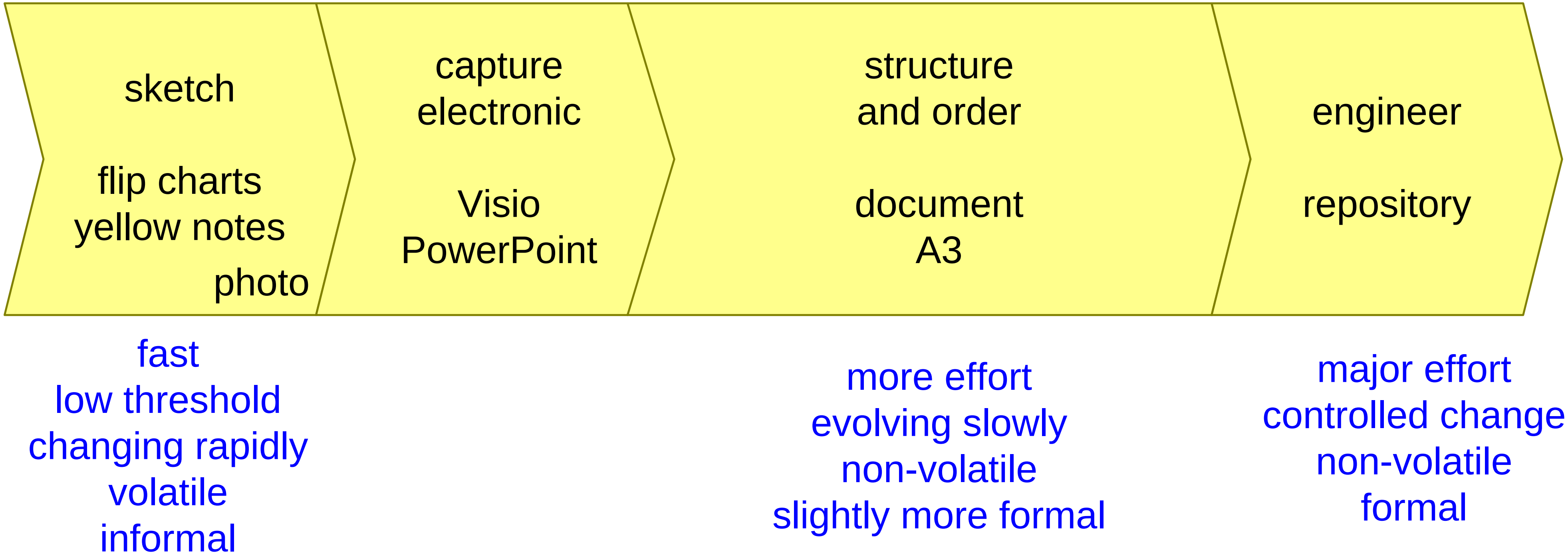
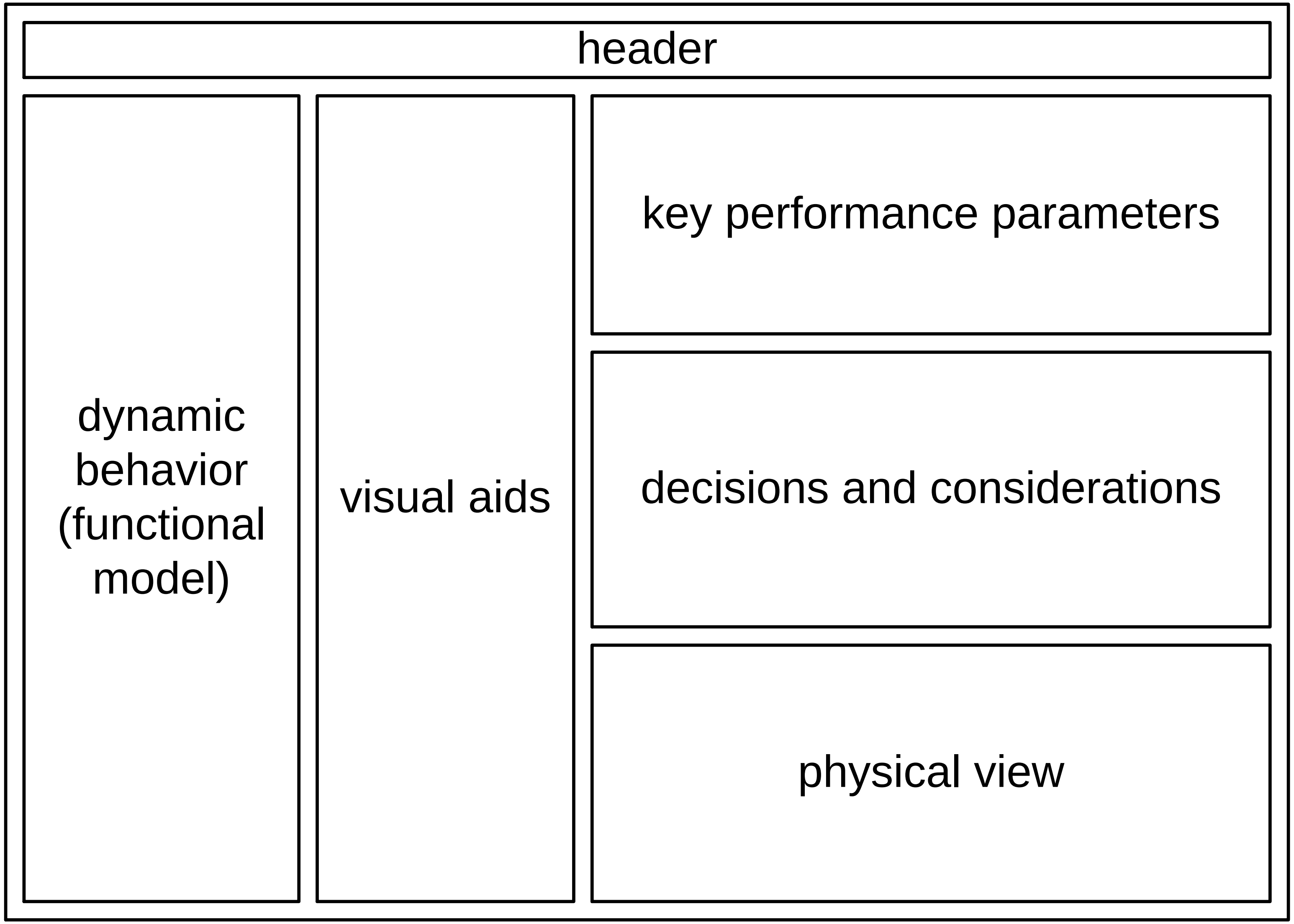
version: 0.2



Maturing an Architecture Description



Architecture Overview A3



simplified from http://www.gaudisite.nl/BorchesCookbookA3architectureOverview.pdf

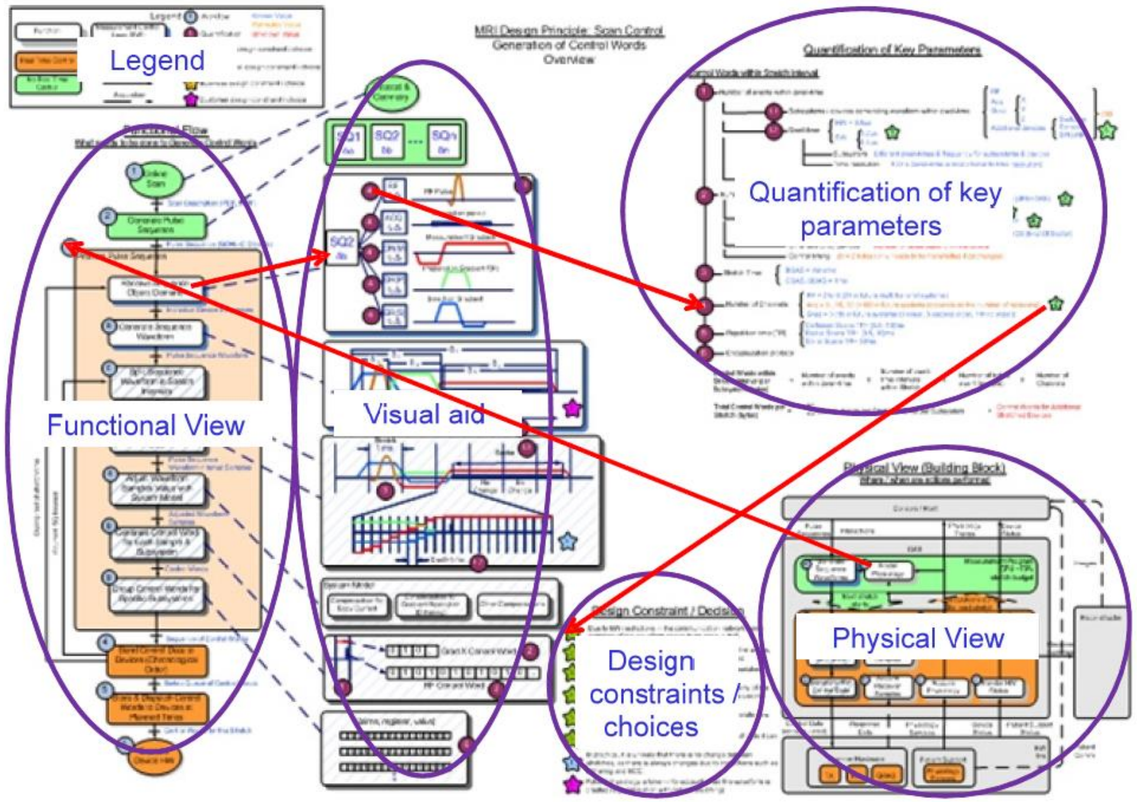
A3s to Capture Architecture Overviews

multiple related views

quantifications

one topic
per A3

capture
"hot" topics

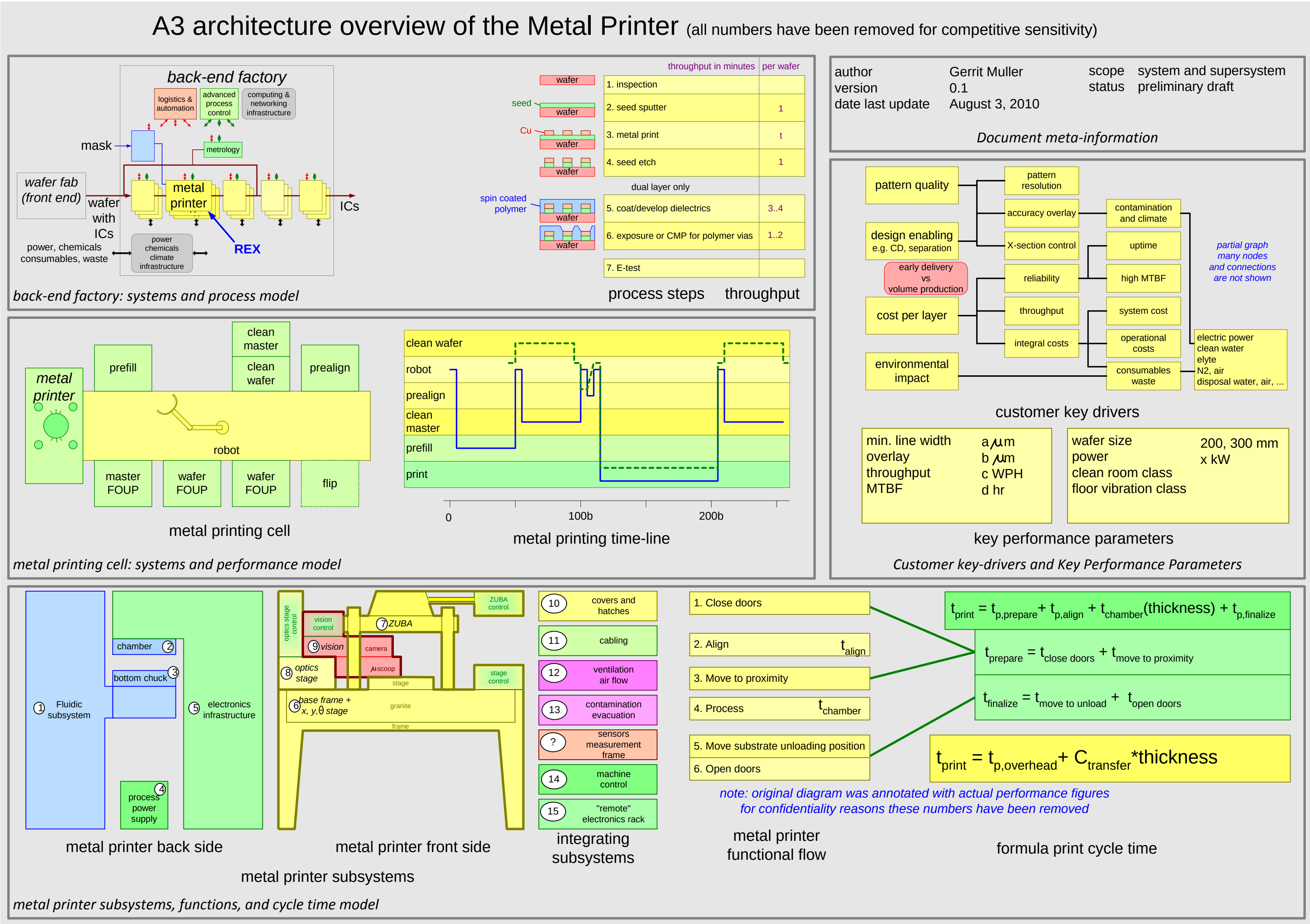


source: PhD thesis Daniel Borches http://doc.utwente.nl/75284/

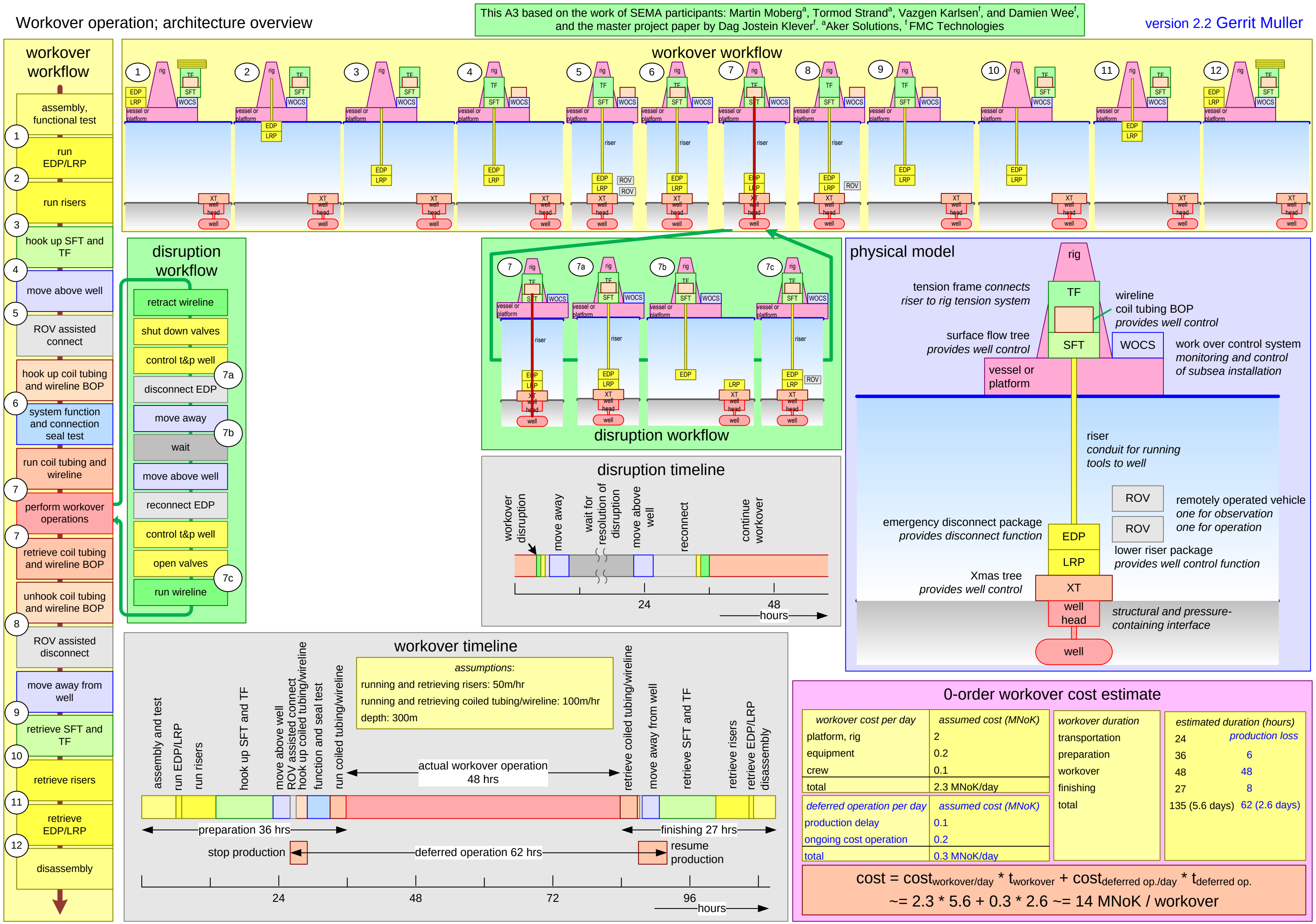
digestable
(size limitation)

practical
close to stakeholder experience

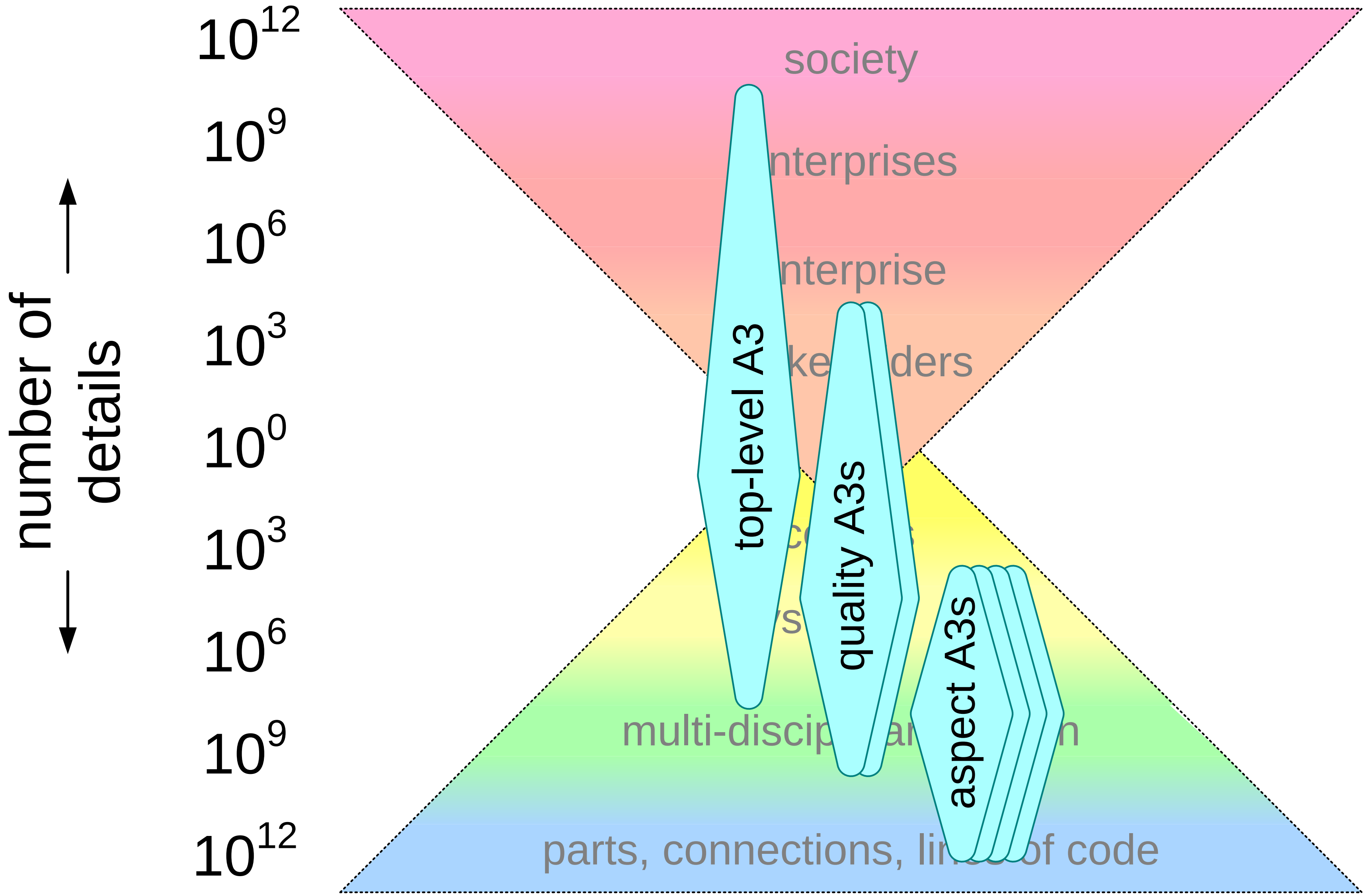
Example of A3 Architecture Overview



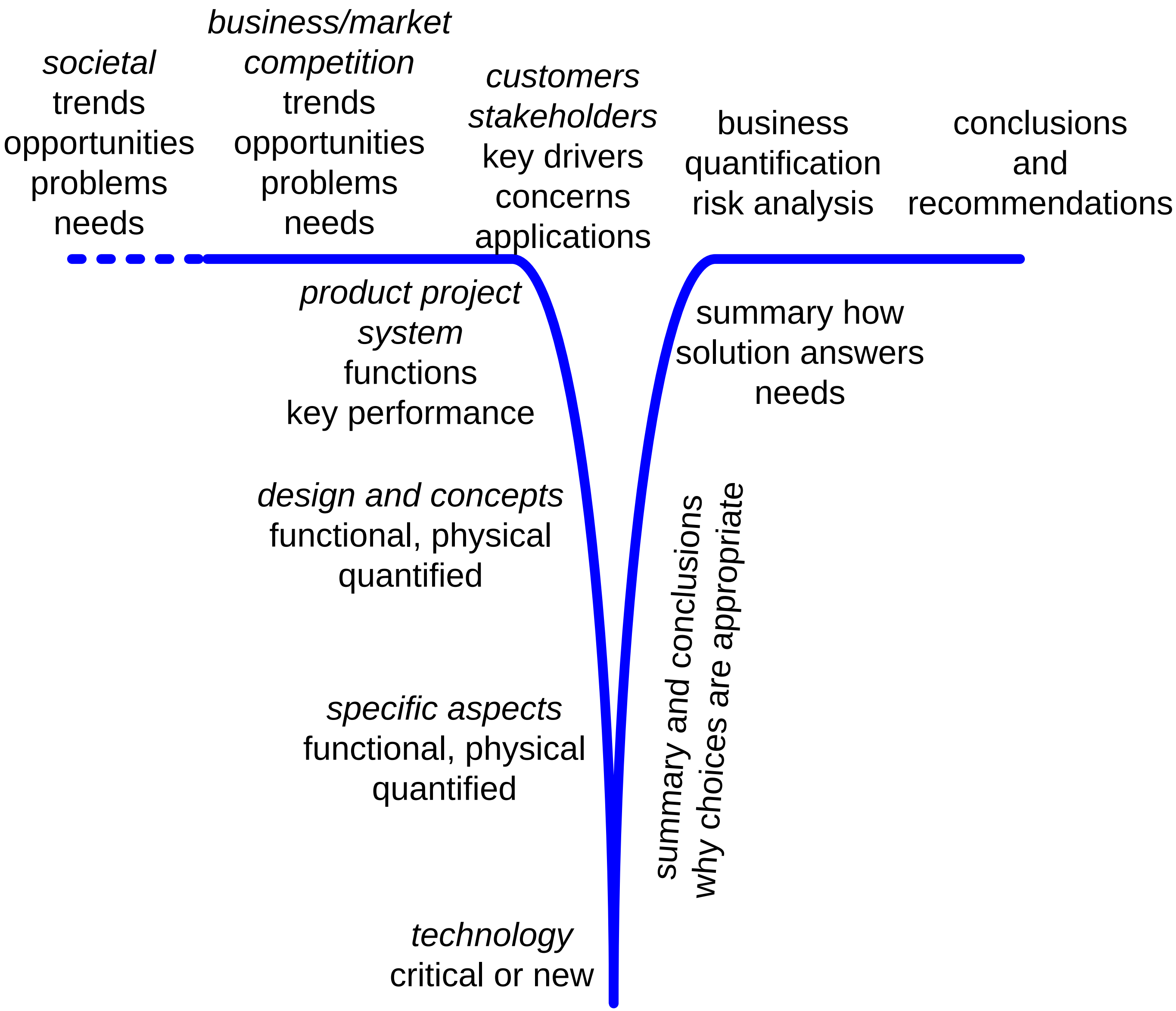
Example of SubSea A3 Architecture Overview



Multiple Levels of A3s



T-shape Presentation



Guidance from ArchitectingForum.org

1.1 One of several prerequisites for architecture creative synthesis is the definition of **5-7 specific key drivers** that are critical for success, along with the rationale behind the selection of these items

2.1. The essence of a system can be captured in about **10 models/views**

2.2. A **diversity** of architecture descriptions and models is needed: languages, schemata and the degree of formalism.

2.3. The level of **formality** increases as we move closer to the implementation level.

from http://www.architectingforum.org/bestpractices.shtml

Exercise Wrap-Up

Capture your work done during the course, e.g. **make photos** of the flip charts.

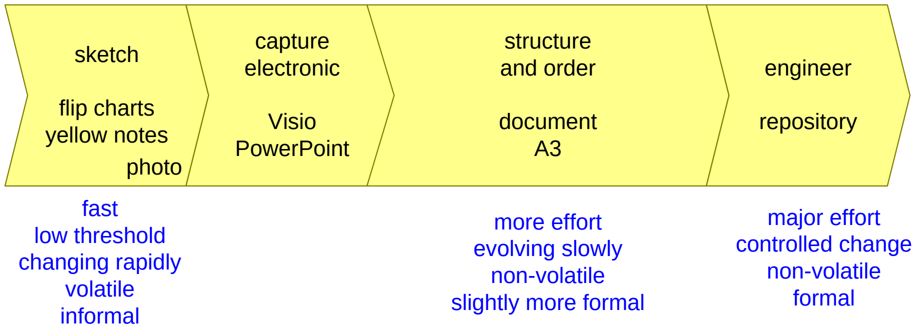
Make a list of **questions**, **assumptions**, biggest **uncertainties** and **unknowns**

Make a list of **lessons learned**

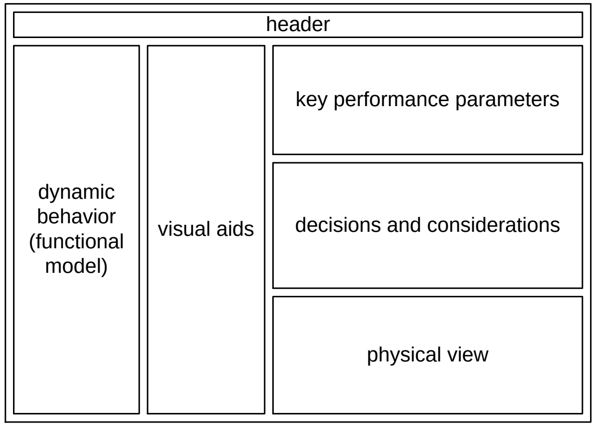
Make a plan for the **homework**

Consolidating Architectures

Maturing, from Light to Heavy

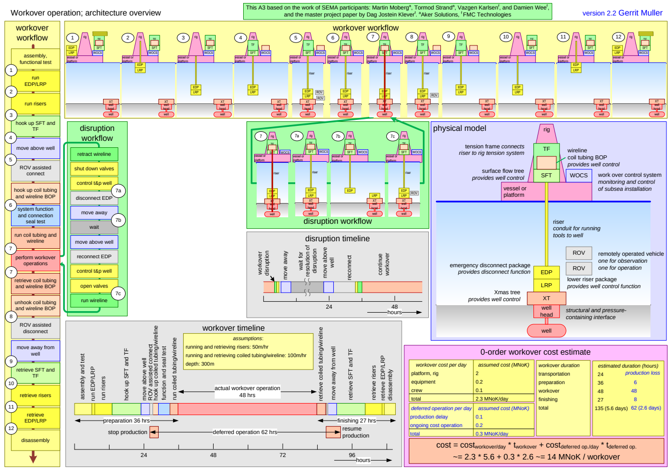


A3 Architecture Overview

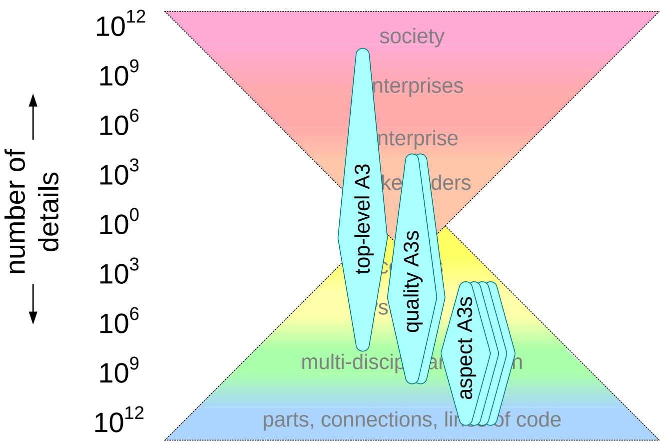


simplified from http://www.gaudisite.nl/BorchesCookbookA3architectureOverview.pdf

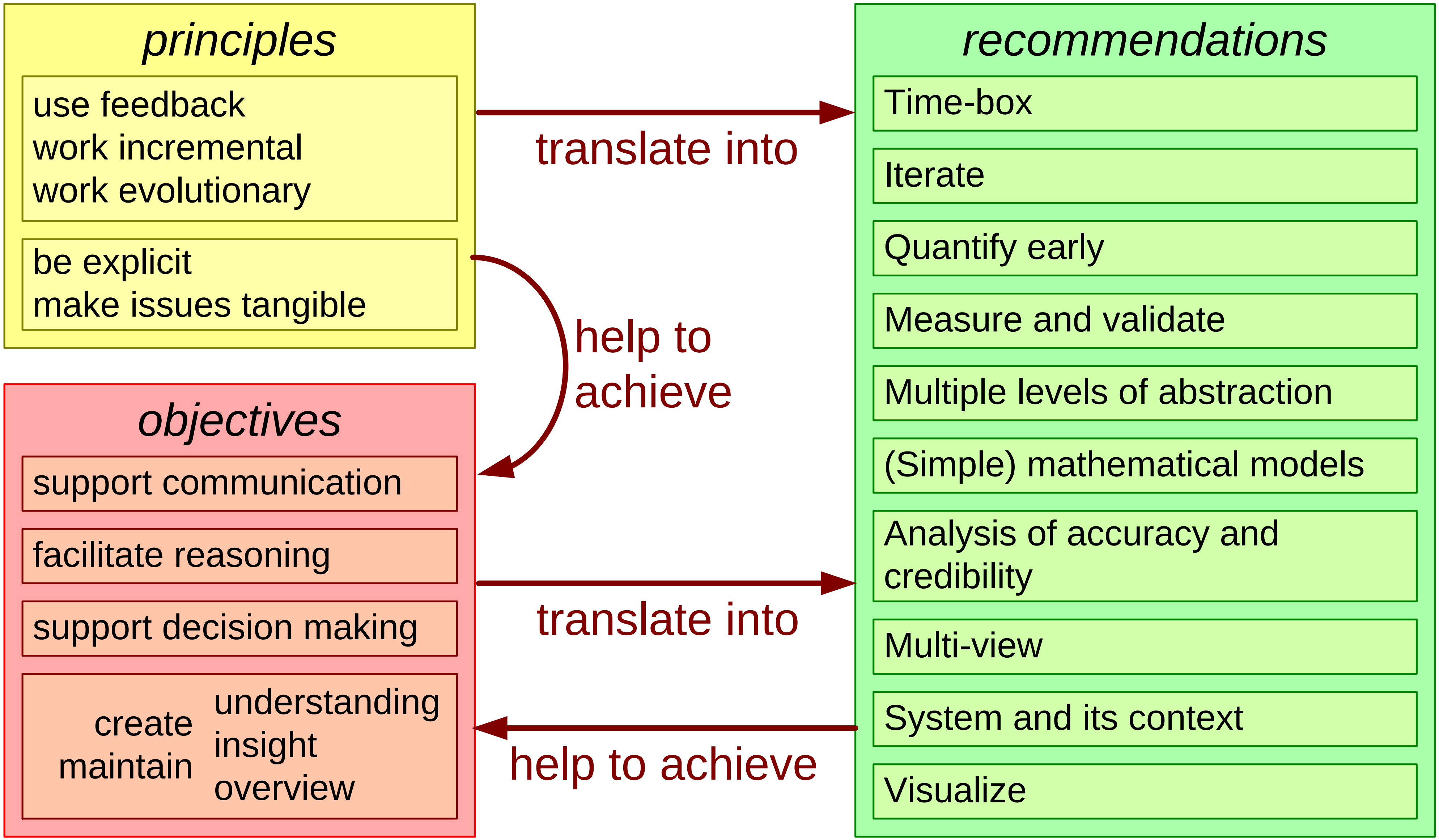
Subsea A3



Multiple Levels of A3s



Recommendations as Red Thread



SEMA Homework Assignment

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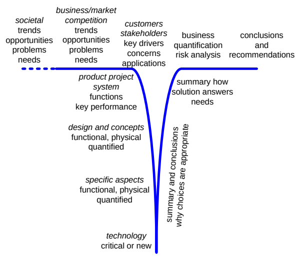
`www.gaudisite.nl`

Abstract

This document described the homework assignment for the SEMA course. The homework is made and delivered incrementally, so that the teacher can provide feedback during the assignment.



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July 3, 2023
status: draft
version: 0.3

Group Assignment

Submit each step to the teacher, and process feedback in the next step

Step 1. weeks 1..3

- Consolidate work of course in 20 slide presentation as baseline.
- Search for answers to the main questions, biggest uncertainties and unknowns, validate main assumptions.
- Elaborate most relevant models.
- Discuss your work with other stakeholders to collect more facts and figures and for erly validation

Step 2. weeks 4..6

- Transform the presentation into a T-shape presentation
- Identify gaps in the “T”
- Make simple models to eliminate the gaps

Step 3 weeks 7..9

- Identify required changes in models made so far, due to increased insight;
- Change one of the models accordingly.
- Evolve the T-shape presentation (max 20 slides); the target audience of this presentation is your management.
- Present to company management
- Identify next models to be made, measurements to be done, or fact finding to take place.
- Update the presentation with feedback from management and a list of future work.

Individual Assignment

Write an individual reflection report after finishing the group assignment, answering the following questions:

> What are the main gaps in the current proposal and presentation? What 3 gaps will you address first, and why?
>
> In retrospect, formulate a problem statement that triggered the outcoming presentation and underlying modeling effort.
>
> What would you do differently if you would have to prepare this presentation again?
>
> How and what are you going to apply elements of this course in practice?

Be specific and use examples.

preferred size 2 A4s, max 4 A4s.

Submission Instructions

Submission instructions

use for all deliverables the following conventions:

filename: SEMA <your name or team> <subject>.<version>.<extension>

e.g. SEMA WOSteam presentation.2.doc

or SEMA John Student individual report.1.docx

email to: <gerrit . muller @ usn . no>

subject: SEMA <subject>

and submit in WiseFlow before the deadline.

"standard" file types preferred, e.g. pdf, jpg, doc, ppt, vsd, docx, xls, xlsx, ppt, pptx