Architectural Thinking

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Abstract

The architect needs an integral view of a system in its context. The level of detail used in the integral view is limited by necessity. This view is based on a much more detailed, but implicit, understanding of system and context. Many experience based methods are used by the architect to reach an explicit understanding of the functionality and performance of the system, black box as well as white box.
The dynamic range of mental architectural activity is explained. The thinking process of the architect is illustrated by means of budgetting, one of the many experience based methods of architects.

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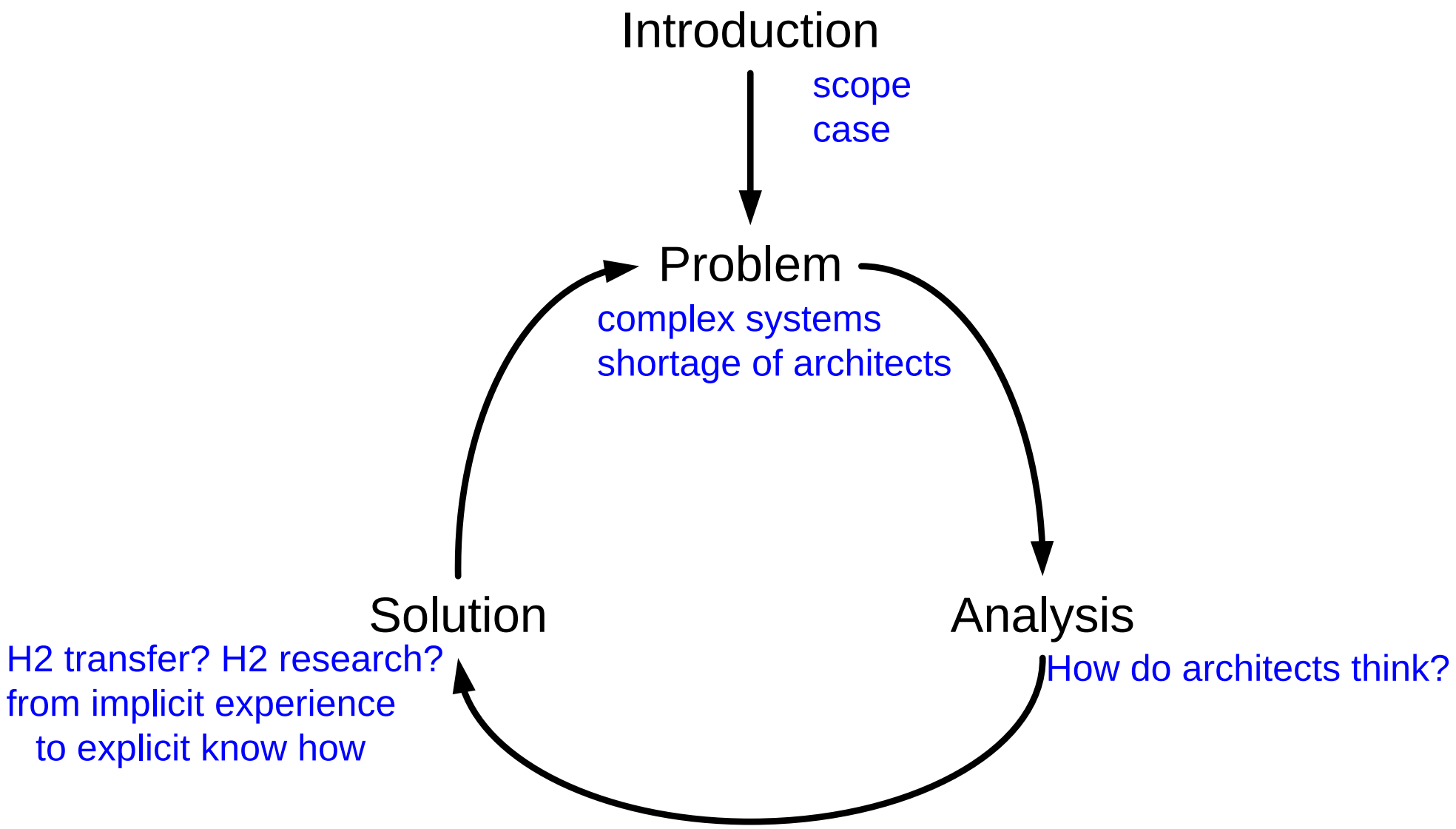
status: concept
version: 1.1

logo
TBD

Outline of the Presentation



Embedded Systems; From Small to Large

chip

GSM

MRI scanner

cardio X-ray system

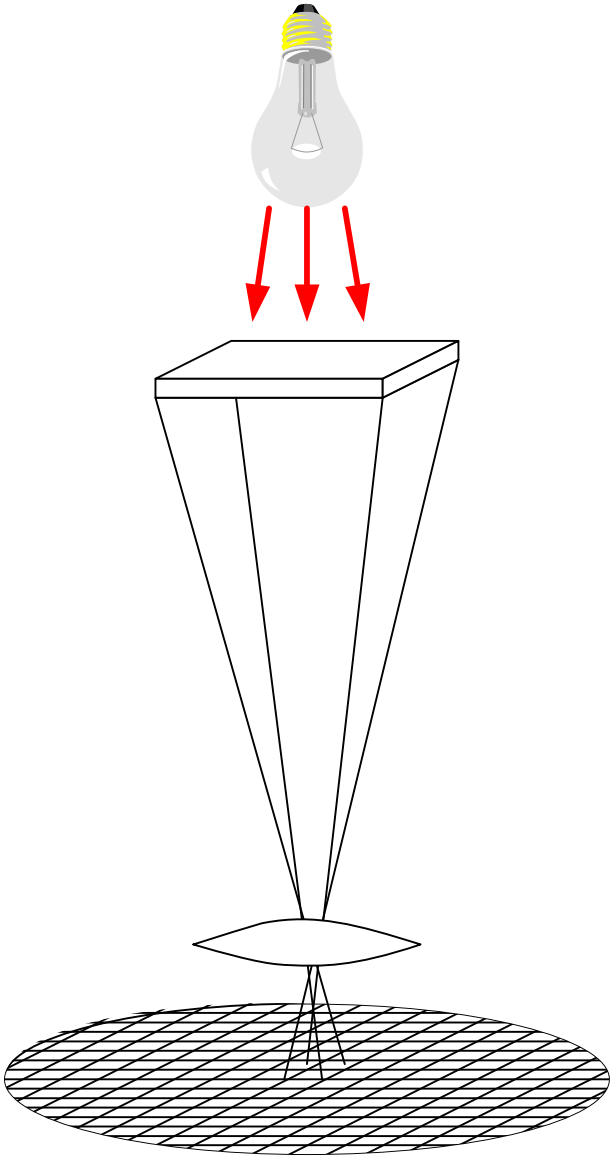
television

printer

waferstepper

Twinscan AT1100

What is a Waferstepper



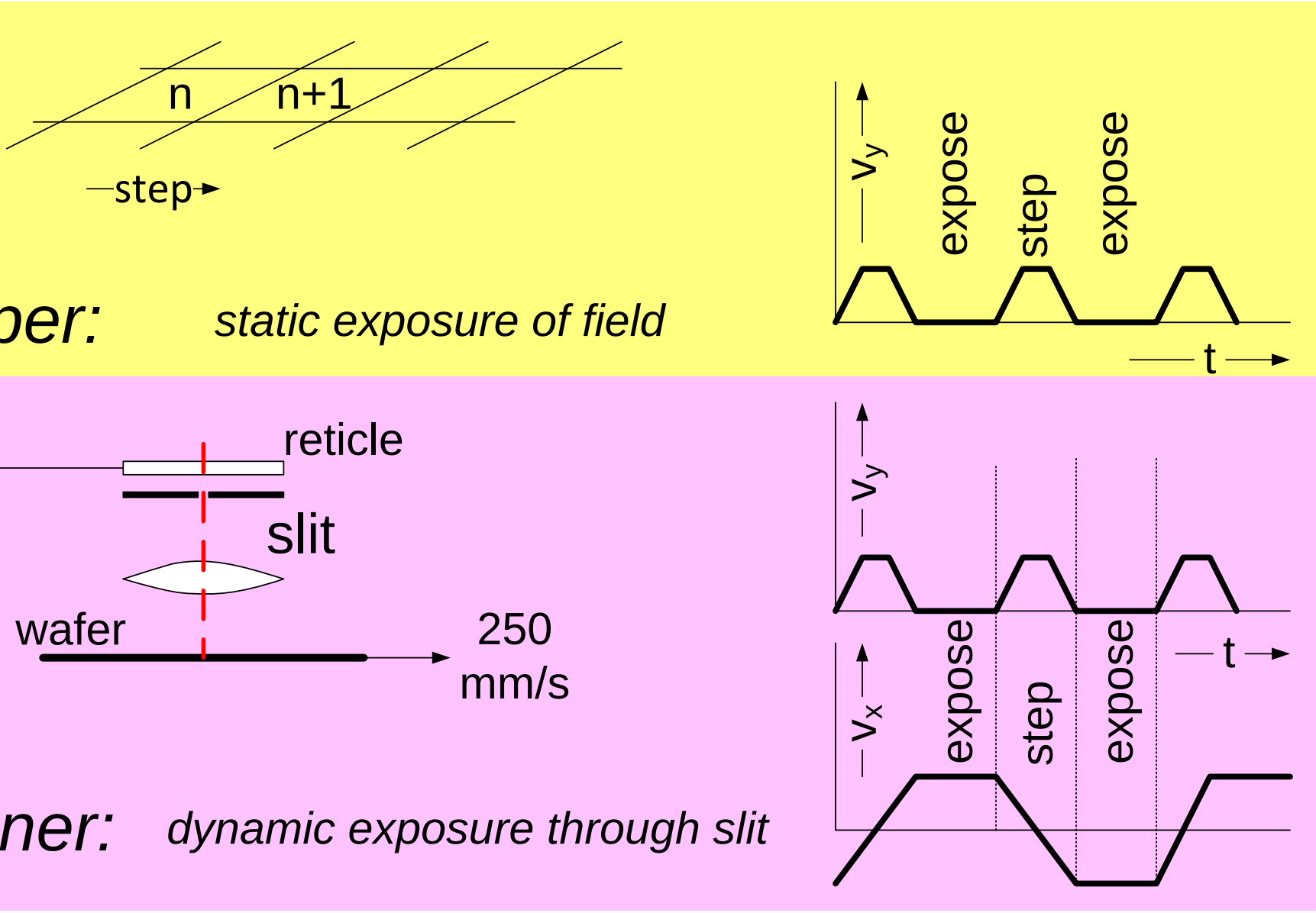
source

reticle

lens

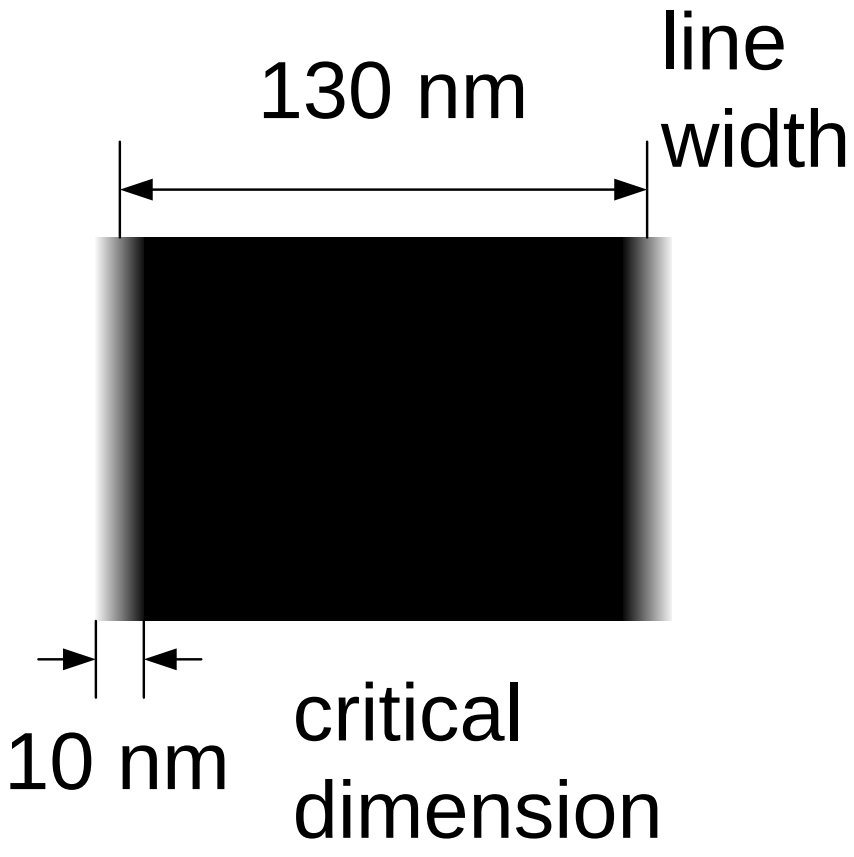
wafer

From stepping to scanning

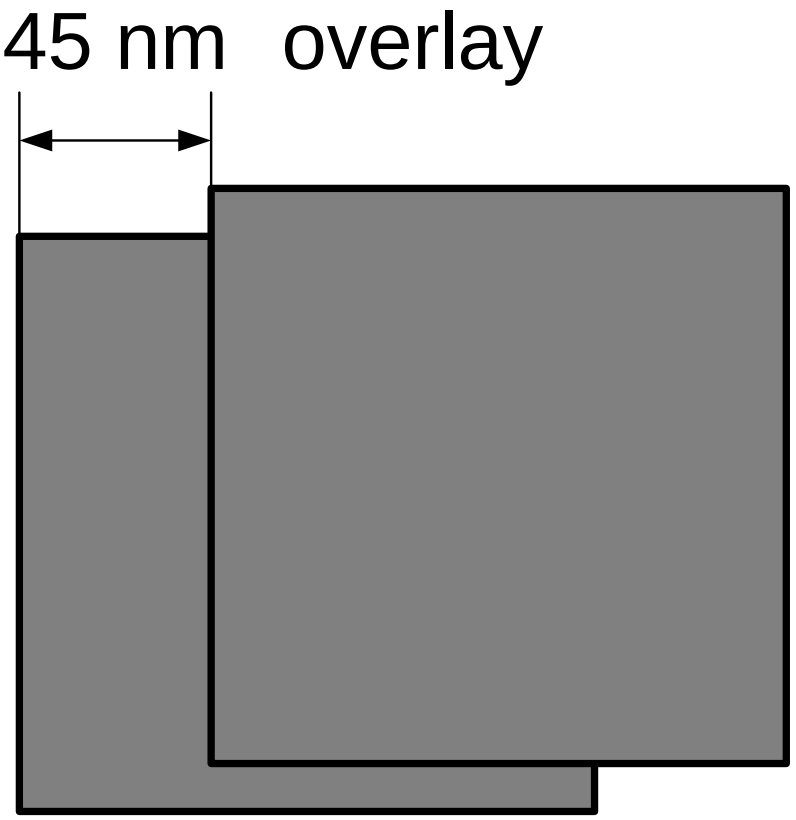


Key specifications waferstepper (2001)

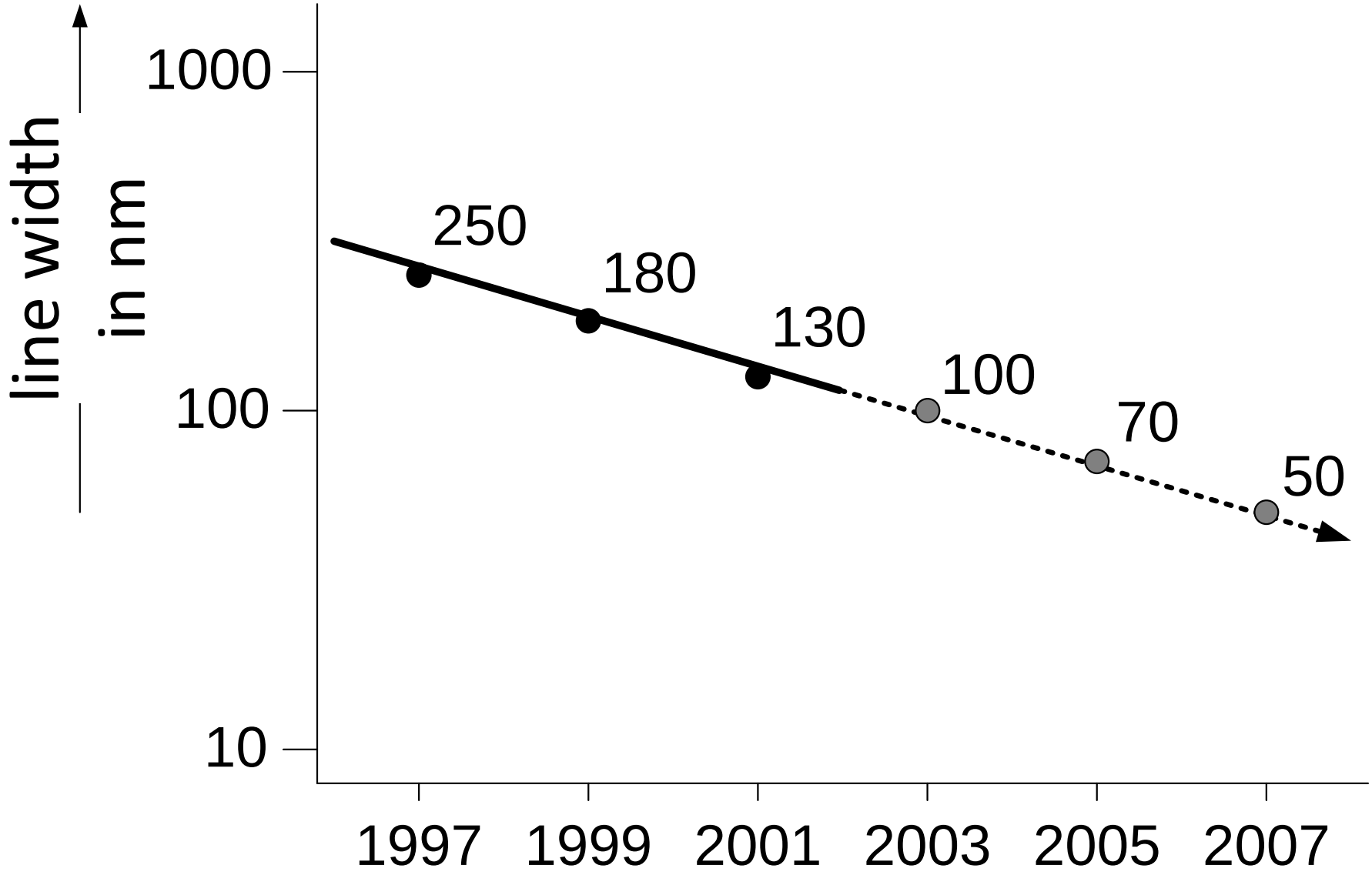
imaging



alignment



Moore's law


line width
in nm
1000
100
10
250
180
130
100
70
50
1997
1999
2001
2003
2005
2007

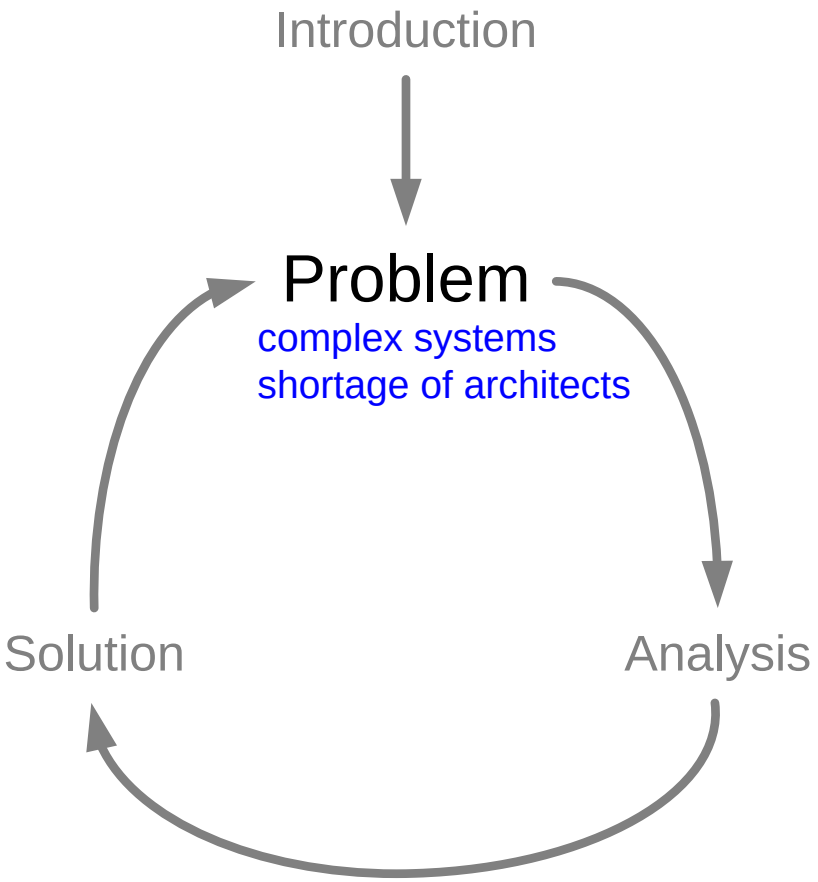
Problem Statement

Embedded systems:
- software intensive > 1 Mloc
- large development teams 10..1000 fte
- multi-disciplinary software, electronics, physics, mechanics,...

Systems Architecting is an art [1]

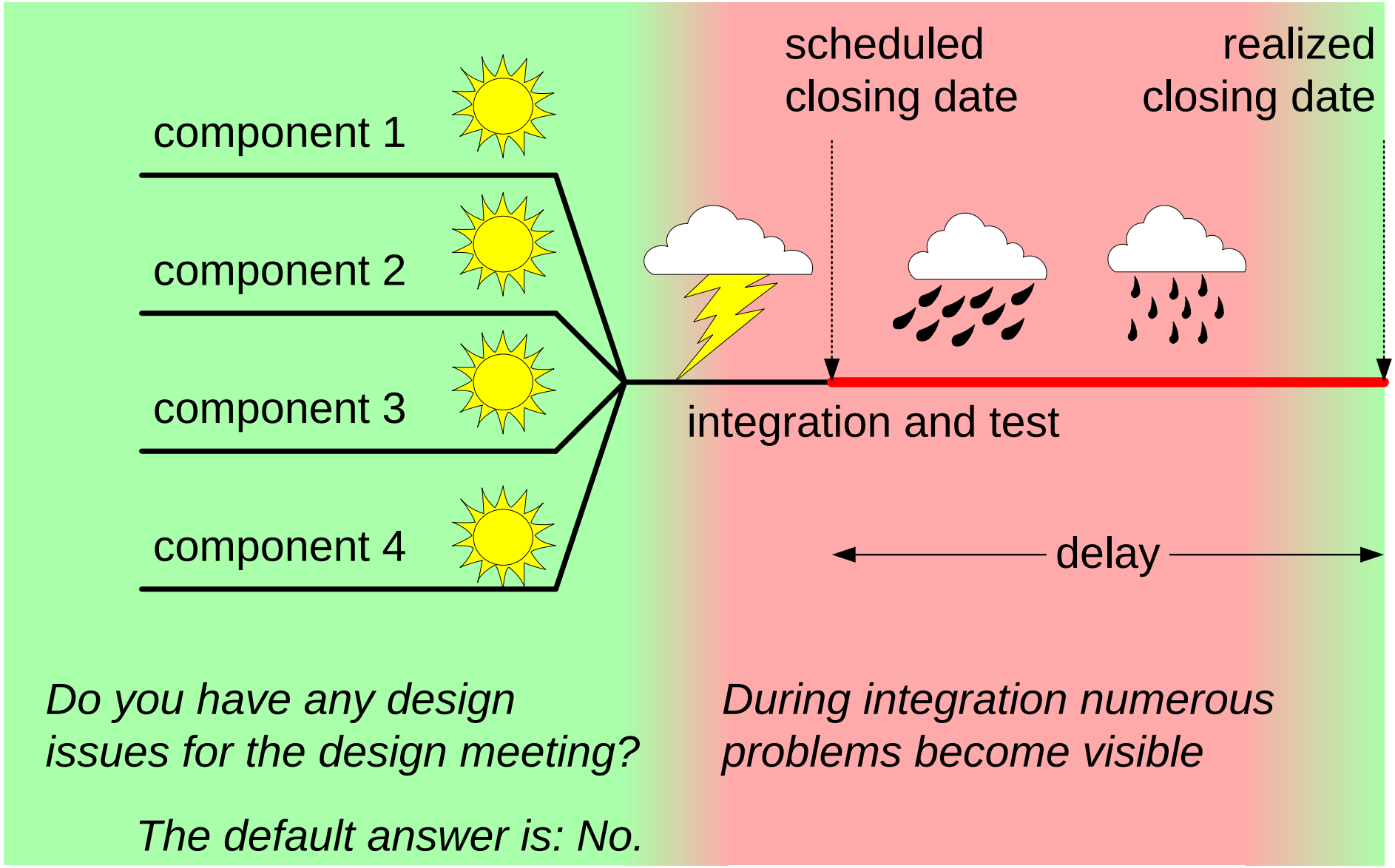
Skilled architects are scarce

Failures, delays, non-performance, cost overruns, dissatified customers

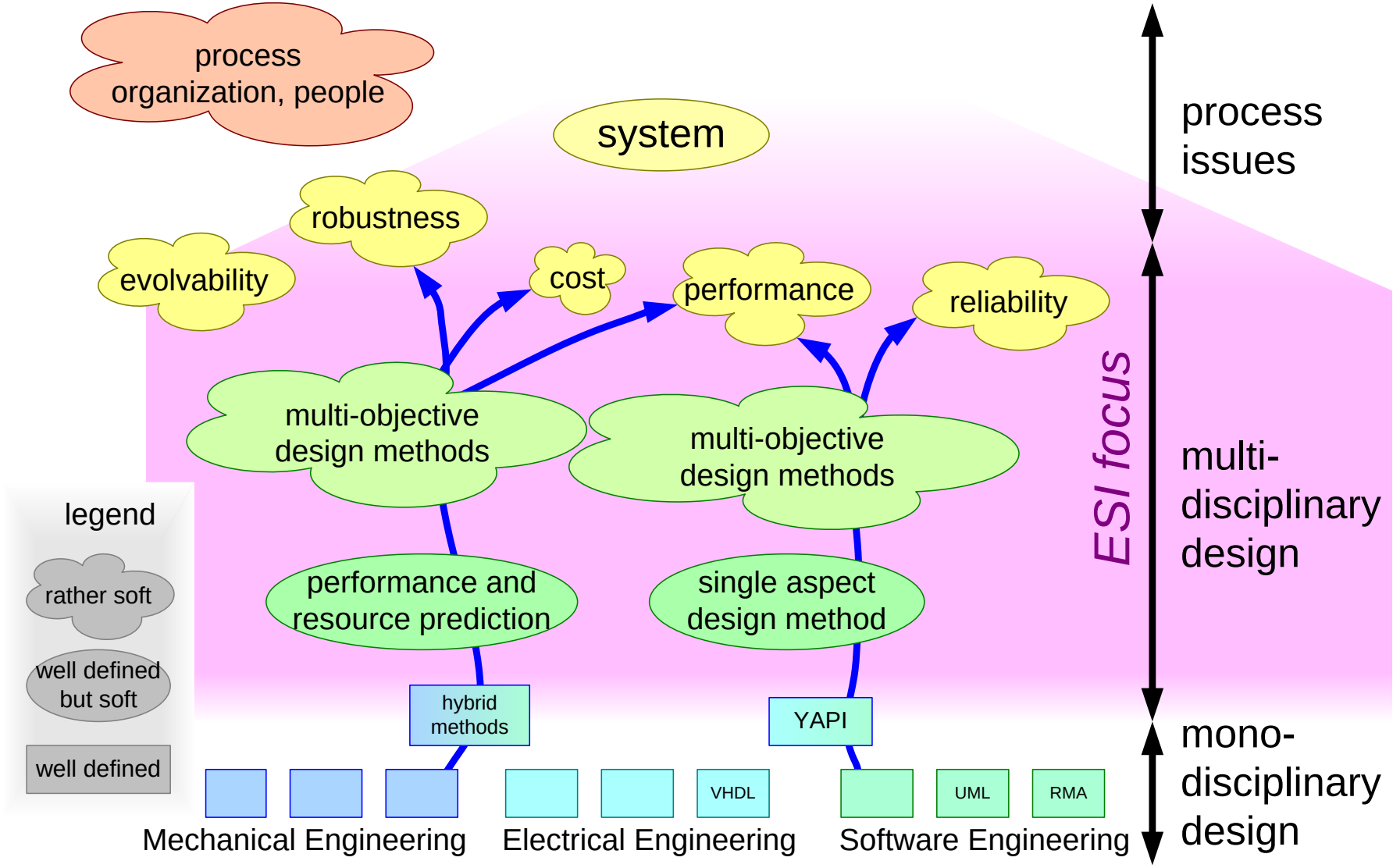


[1] Eberhardt Rechtin and MarkW. Maier. *The Art of Systems Architecting.*

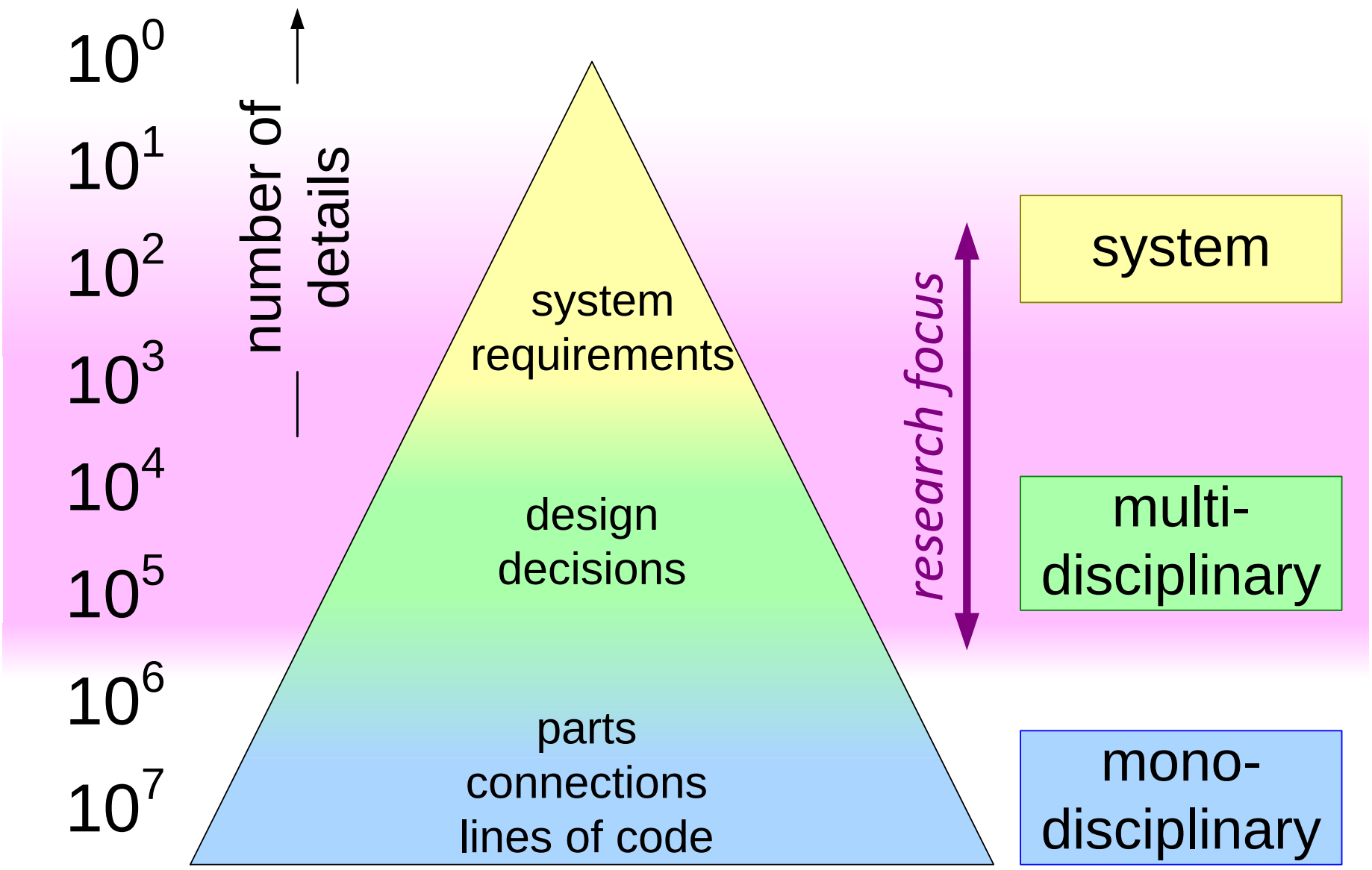
Symptom: Delays appear during Integration



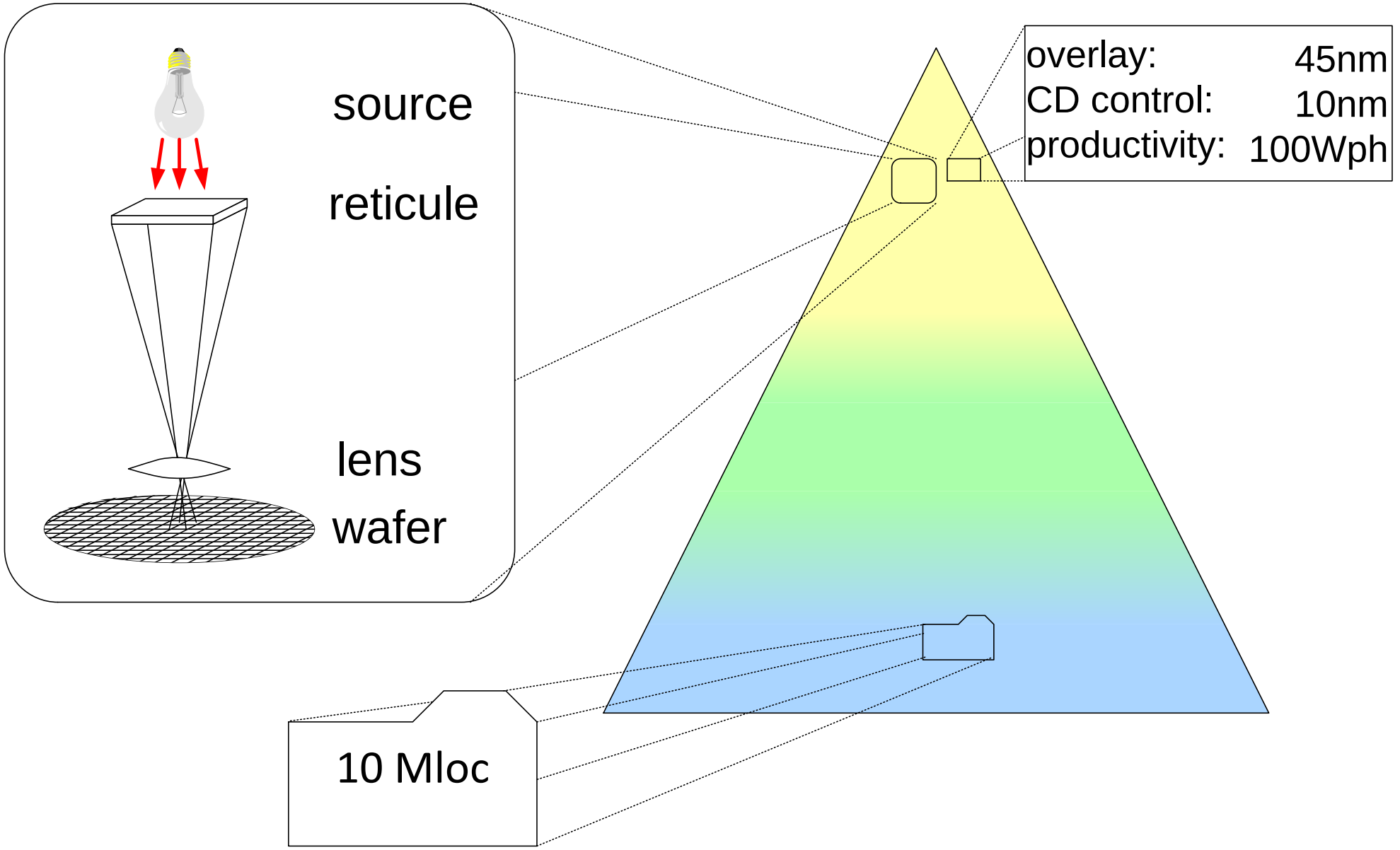
From Mono-Disciplinary to System



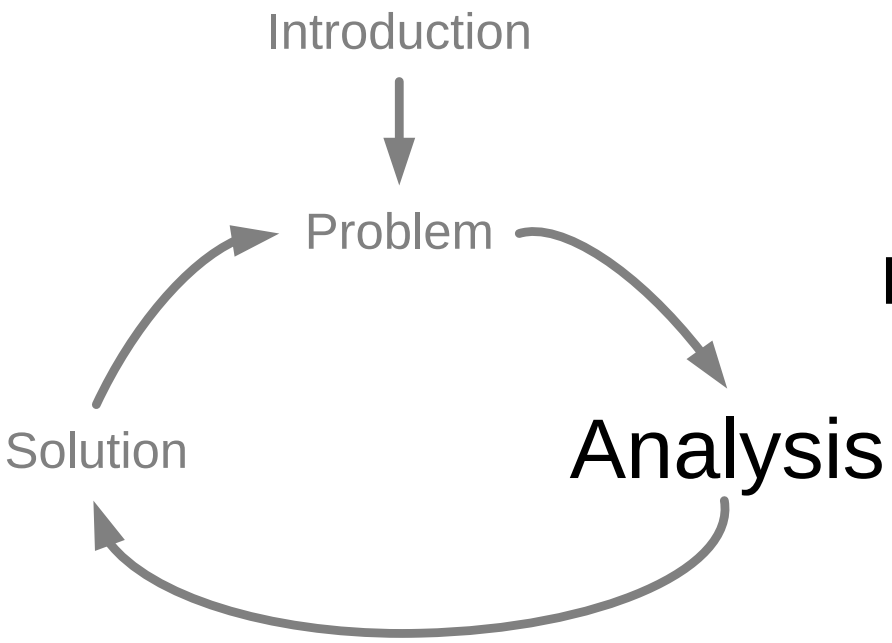
Exponential Pyramid, from requirement to bolts and nuts



How to go from System Level to Detailed Designs?



Analysis



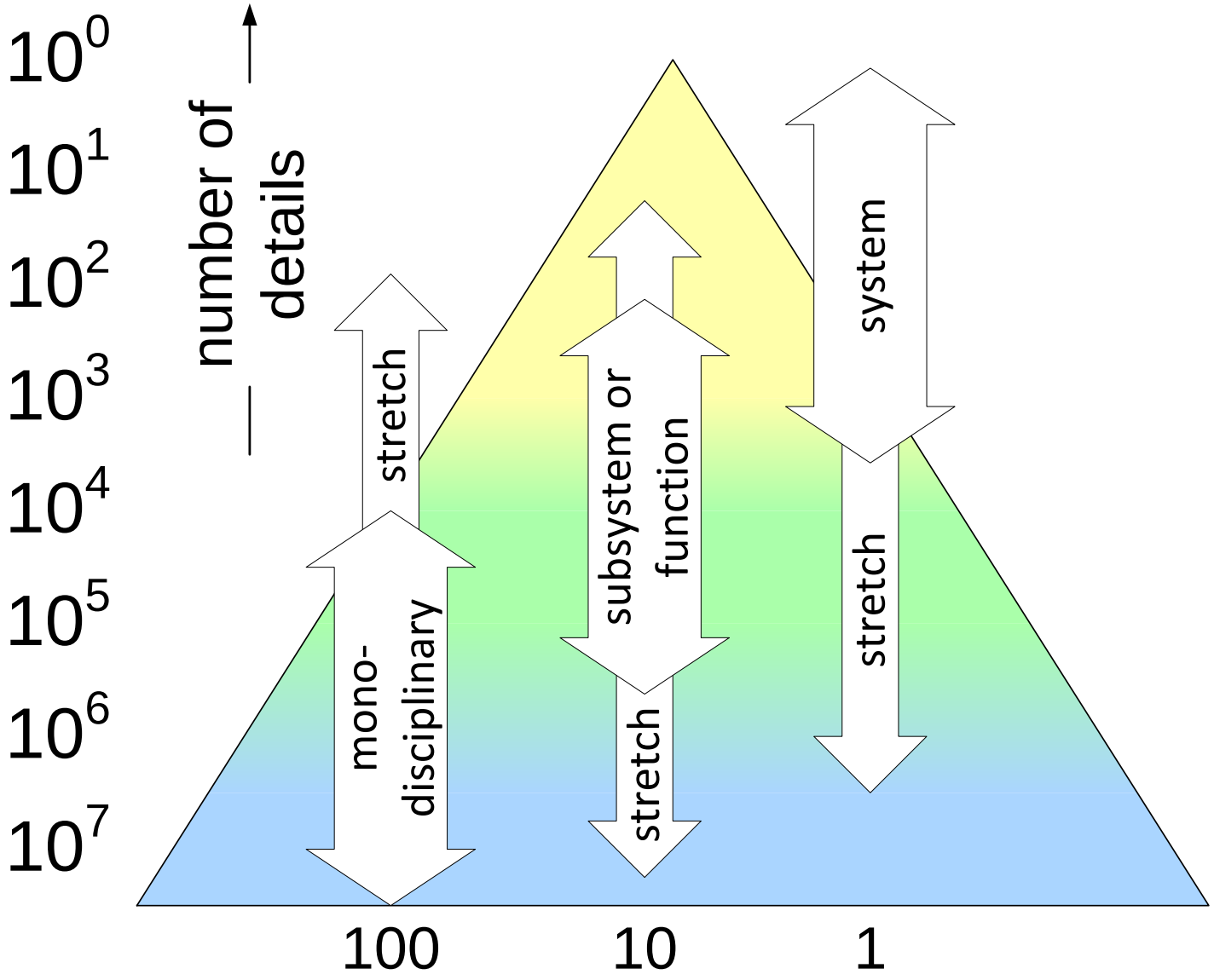
How to cope with dynamic range?

- multiple people
- overlap
- stretch

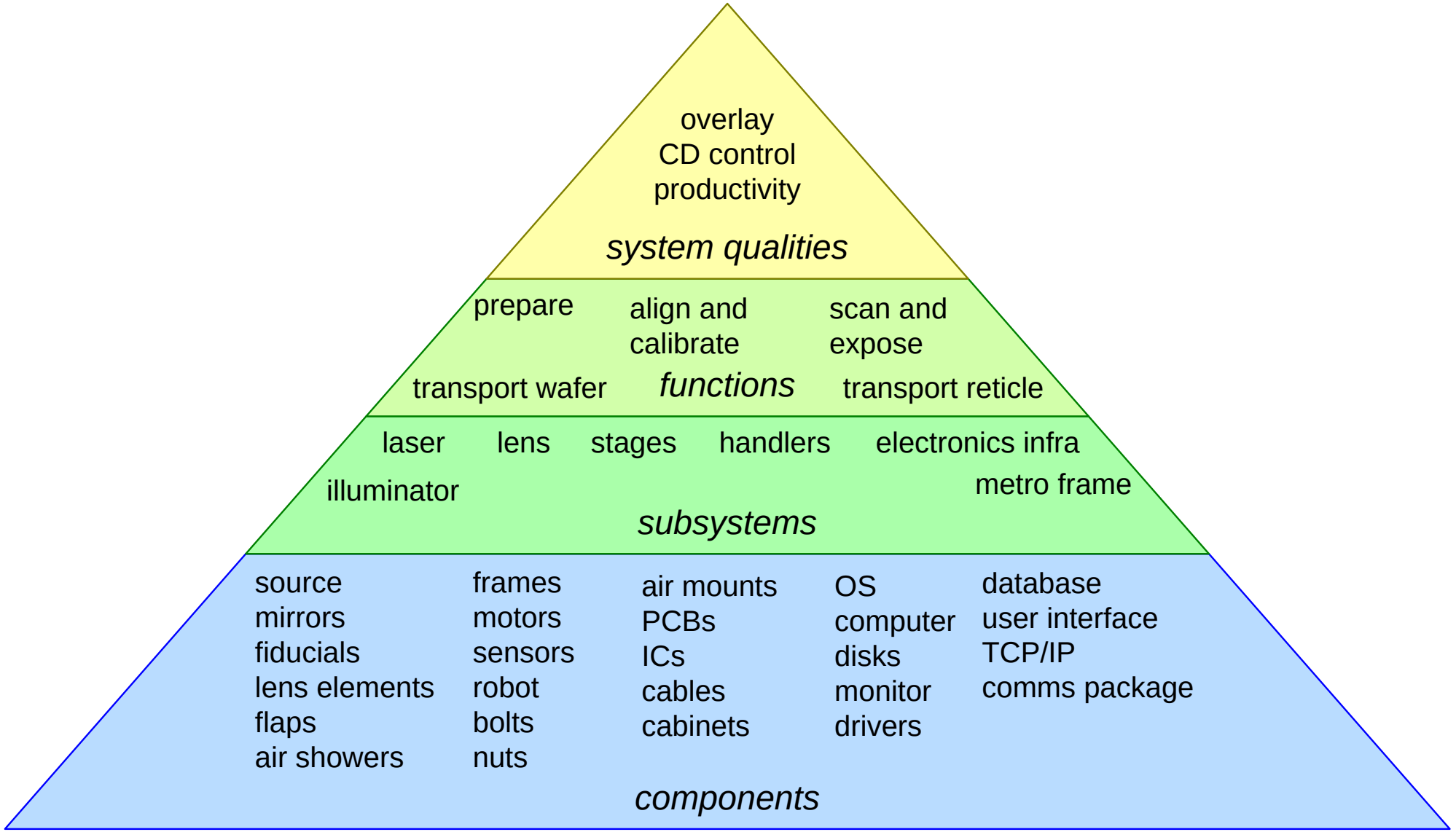
How do skilled architects work?

- viewpoint hopping
- fast iterations
- from vague to tangible
- integrating

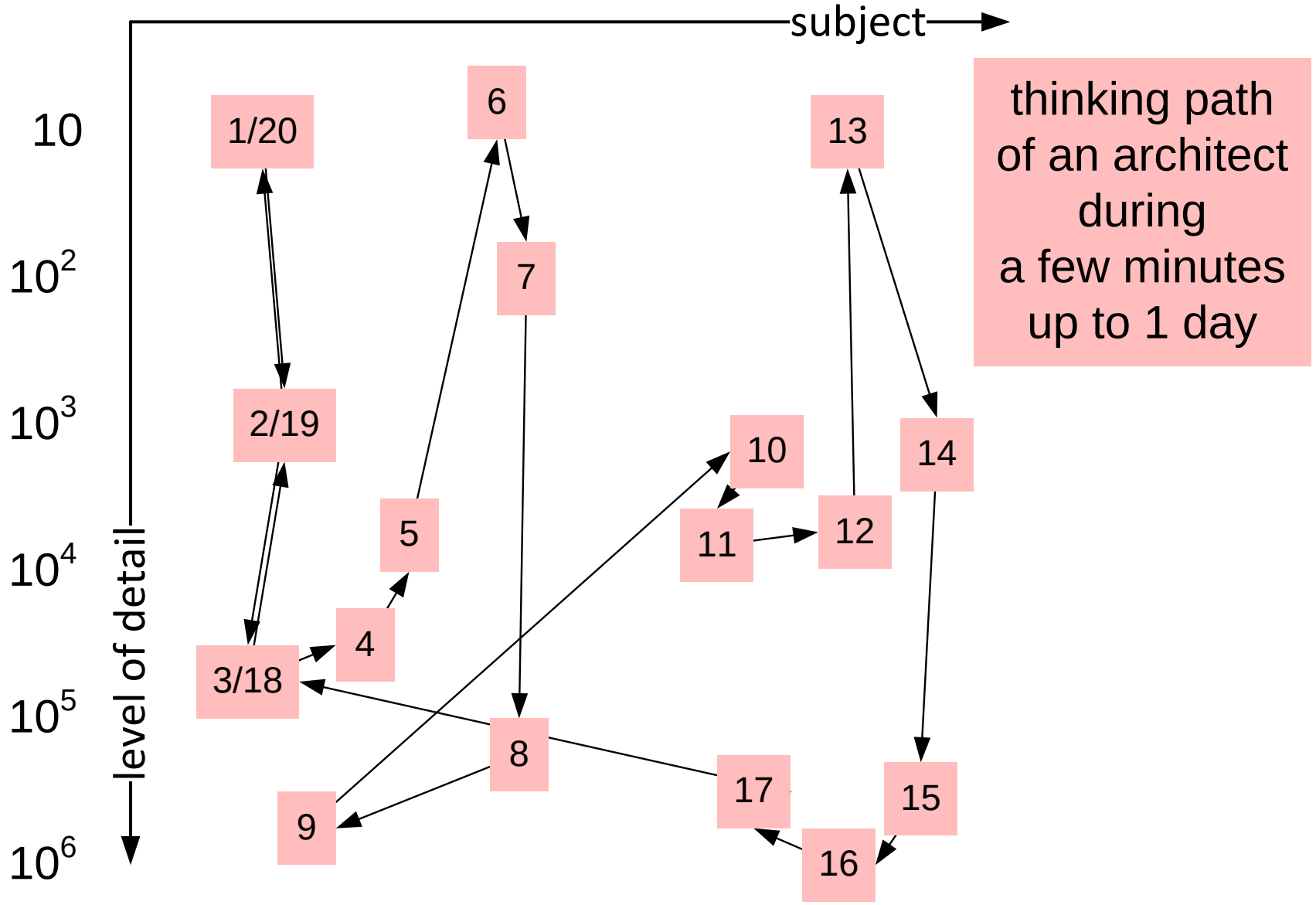
Major Bottleneck: Mental Dynamic Range



From Components to System Qualities



How does an Architect Work? Experience Based!



Examples of Experience Based Methods

methods successfully applied in multiple domains:

- key driver model;
- context modeling;
- cost of ownership modeling;
- use cases, worst cases
- graph representation for logistics purposes (commercial, goods flow, service)
- mapping functions to products and others (QFD)
- interface specification
- construction decomposition
- functional decomposition
- designing with multiple decompositions
- execution architecture
- performance modeling
- micro benchmarking
- **budget-based design**
- safety, reliability and security analysis, for example FMEA
- work break down structure
- integration plan
- quality checklist
- story telling

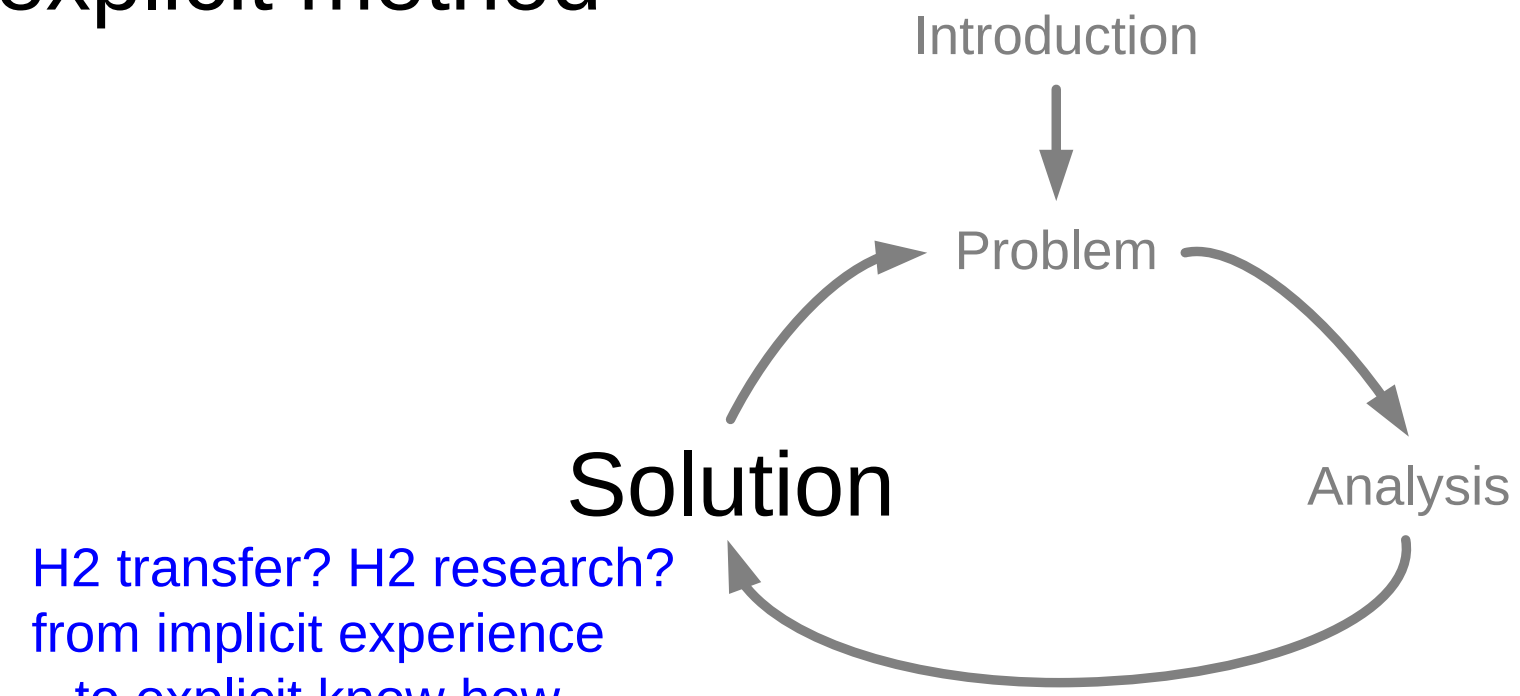
domains where these models have been applied:

waferstepppers
health care
electronics infrastructure projects
document handling
consumer electronics
semiconductors

the budget-based design method will be discussed as applied in waferstepppers, health care, and document handling

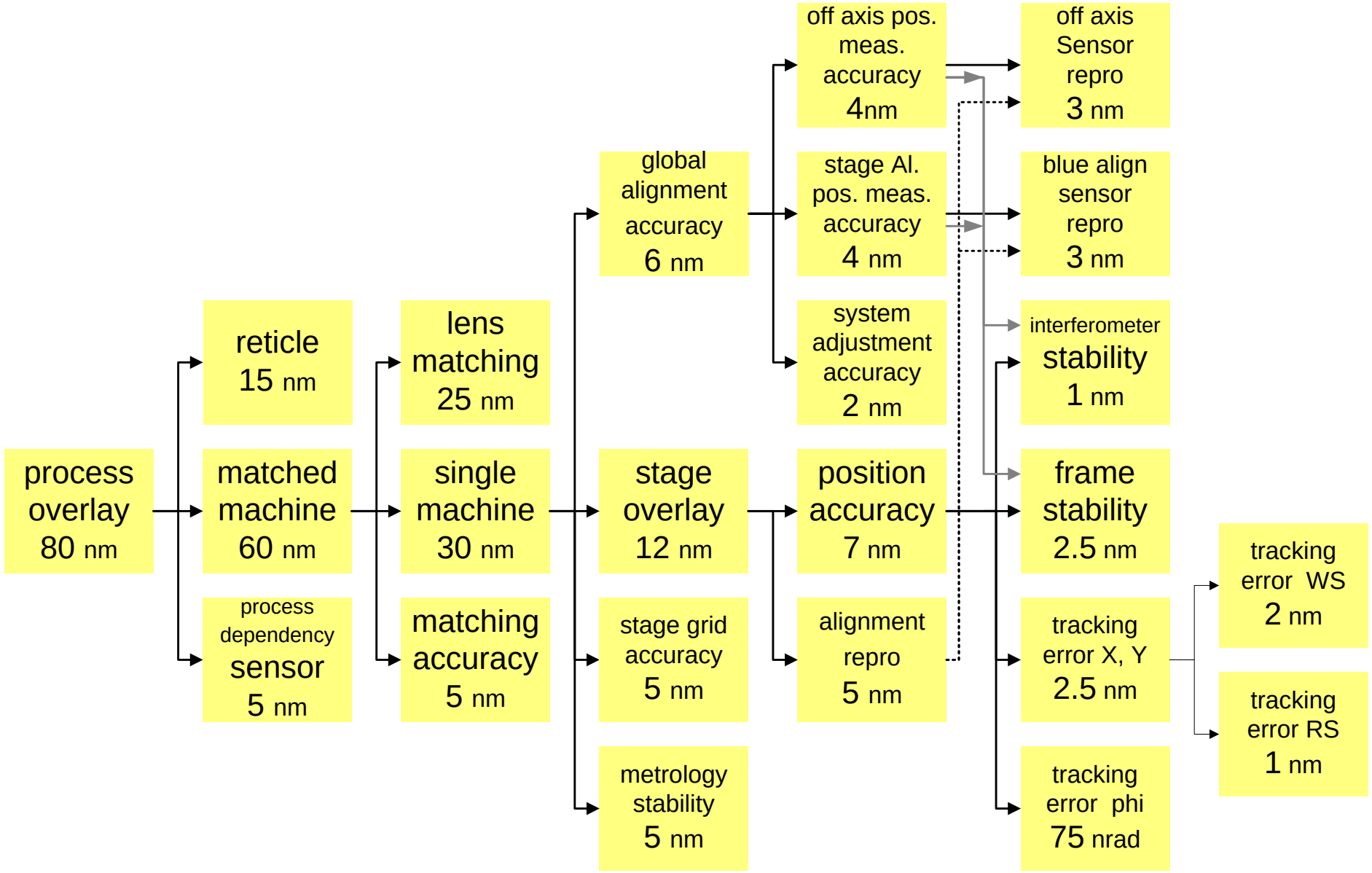
this list of methods based on:
CAFCR: A Multi-view Method for Embedded Systems Architecting; Balancing Genericity and Specificity
(Muller 2004)

example of implicit experience:
budget based design
Why, What, How, Where, ...?
capture in explicit method

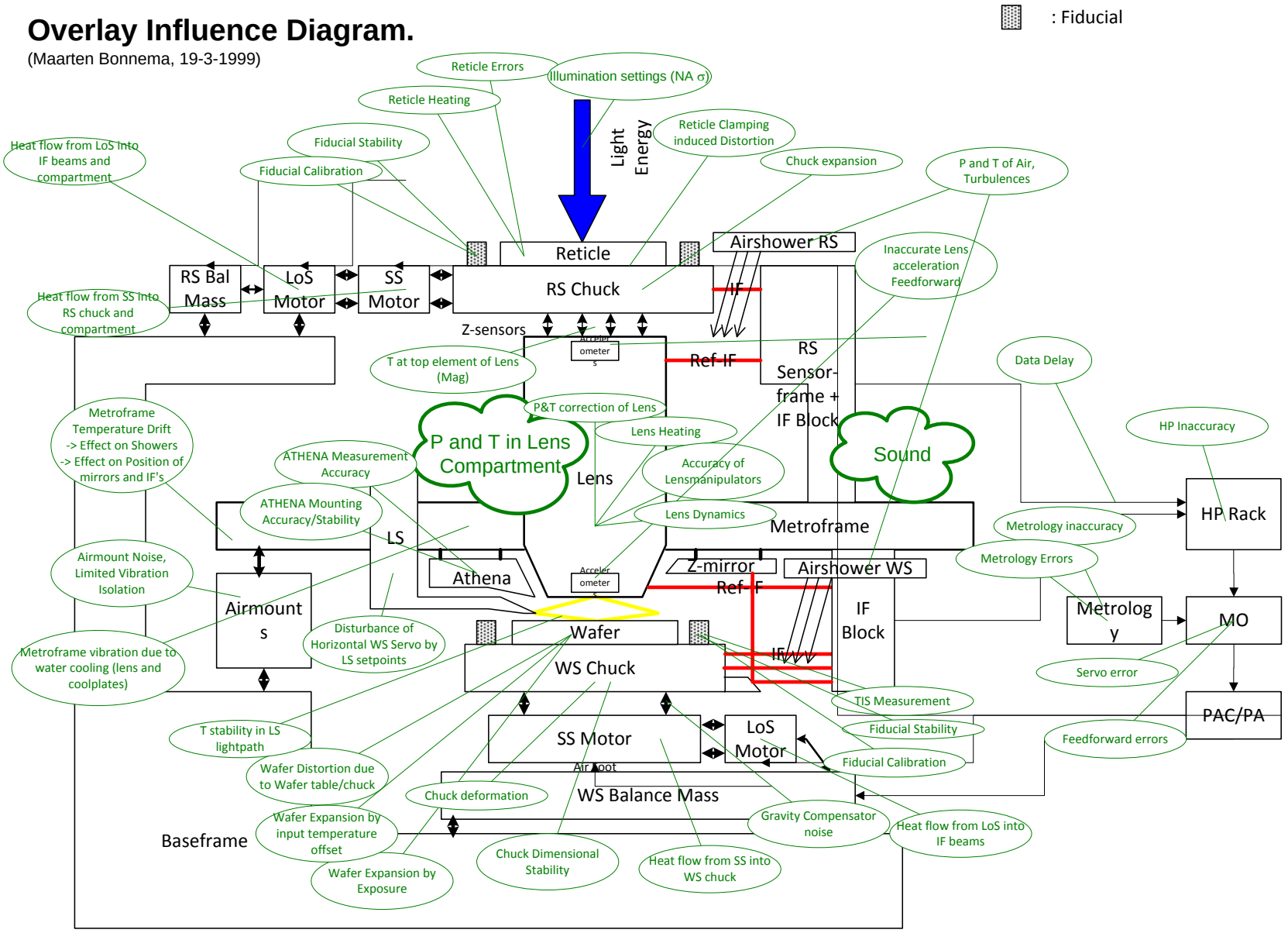


H2 transfer? H2 research?
from implicit experience
to explicit know how

Budgets Applied on Waferstepper Overlay



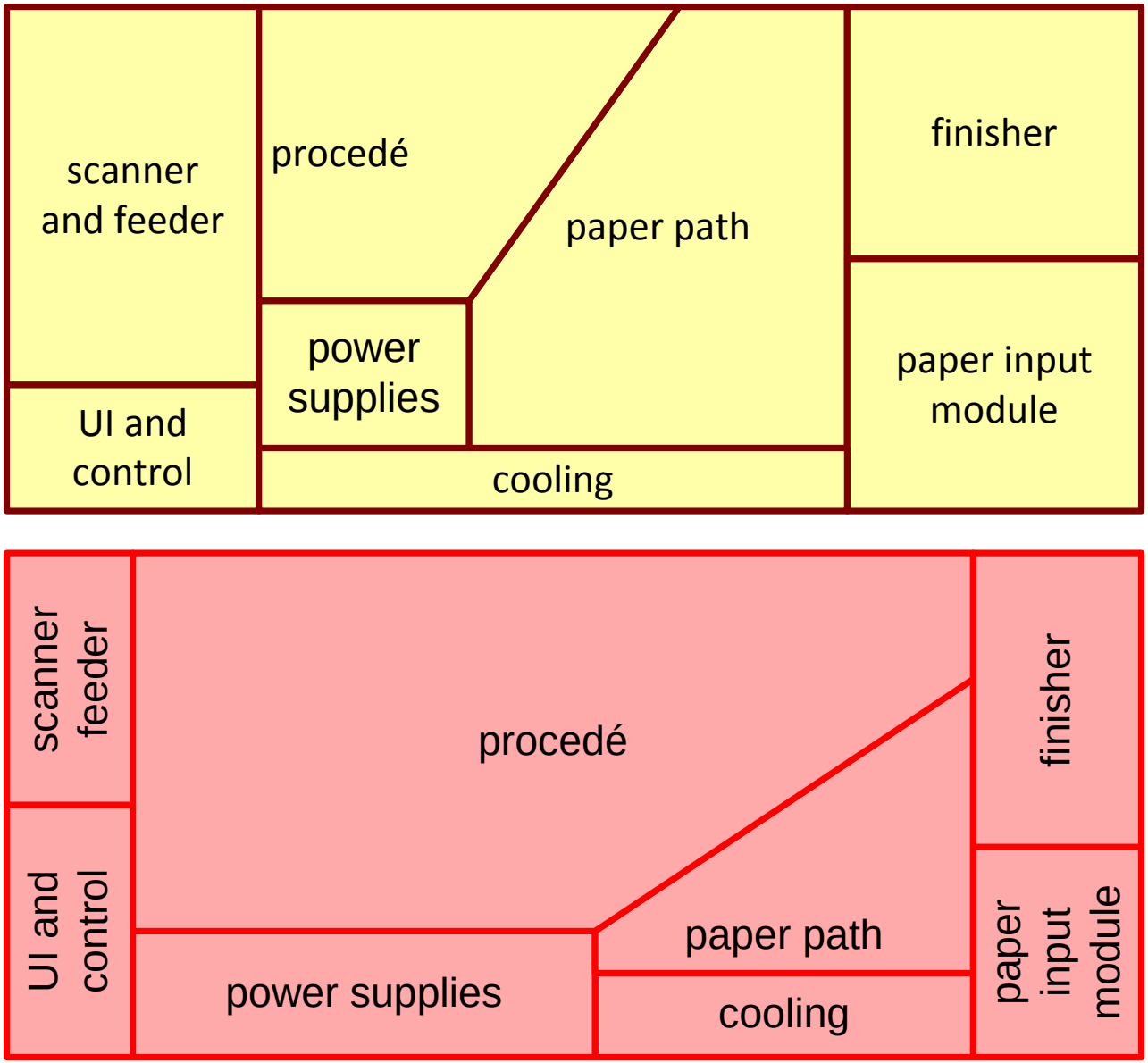
Many Details are Input to the Budget



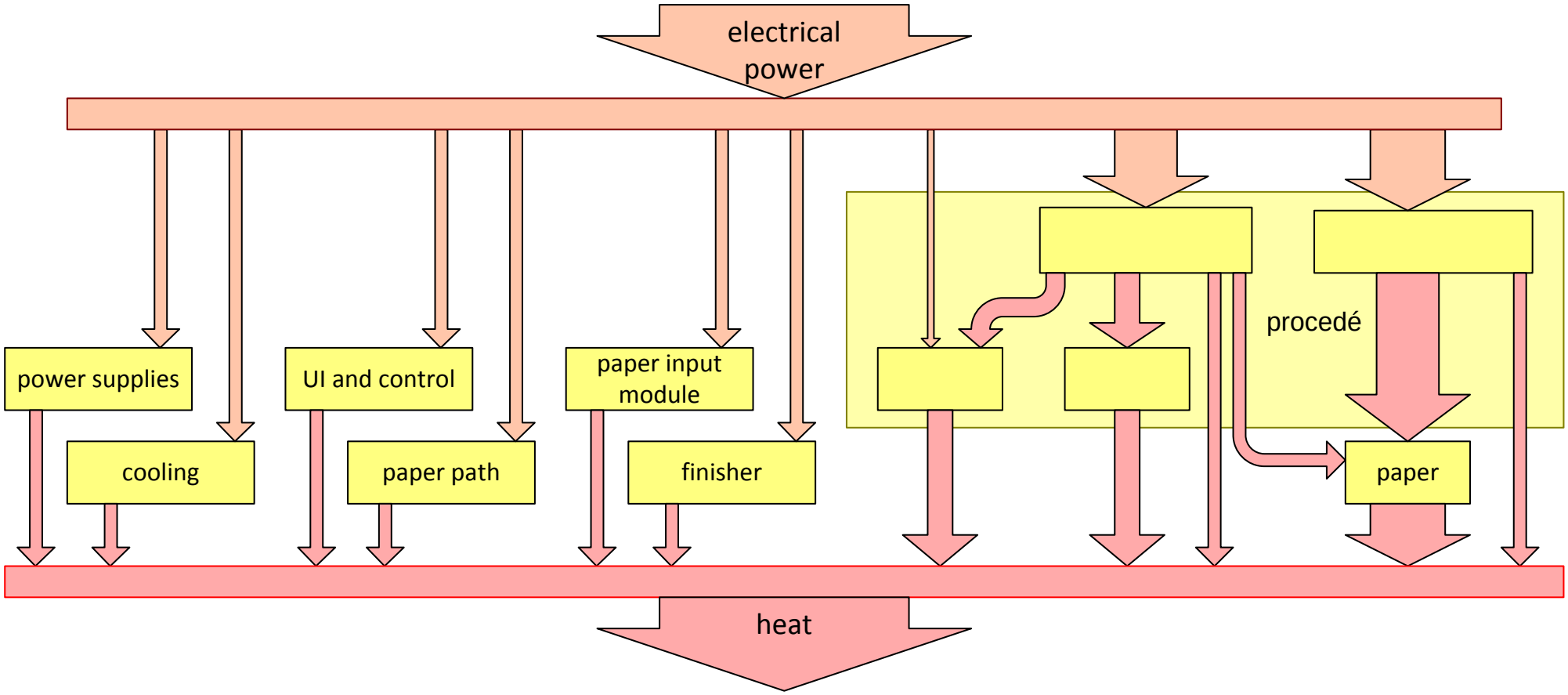
Budgets Applied on Medical Workstation Memory Use

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



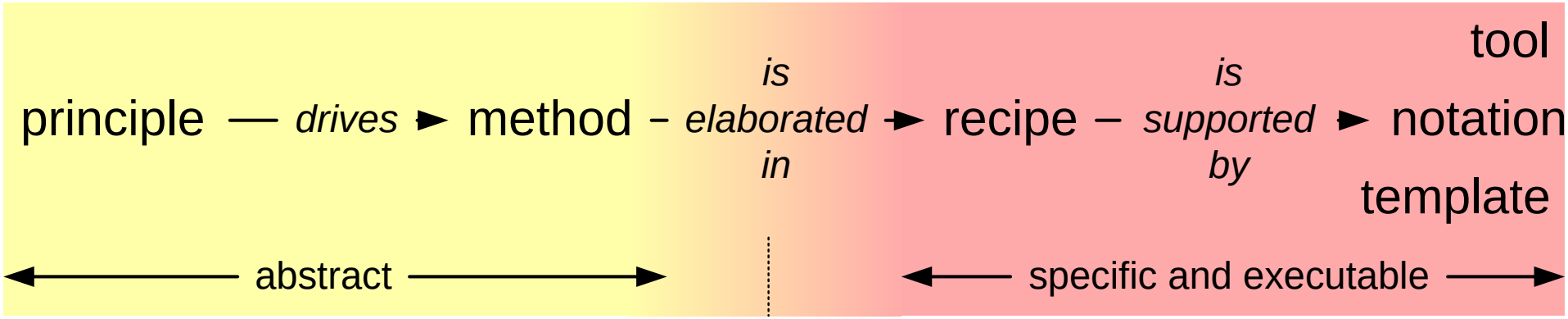
Alternative Power Visualization



So, What are the Open Questions?

- generic nature of methods
  - need for customization
  - need for highly skilled designers
- lack of description
  - concepts
  - how tos
- lack of education in this type of methods
  - where to learn (graduate, postgraduate, postdoc)?
  - which discipline?
- lack of research (exploration and consolidation)
  - when to apply?
  - what are the limits?
  - what are alternative methods?
  - what are the options for (partial) solutions?
- lack of relation with mono-disciplinary methods
  - how to use the results, f.i. how to transform a construction decomposition into a class decomposition?
- lack of tools?

Method abstraction hierarchy

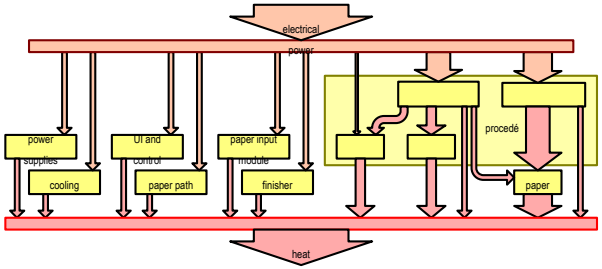


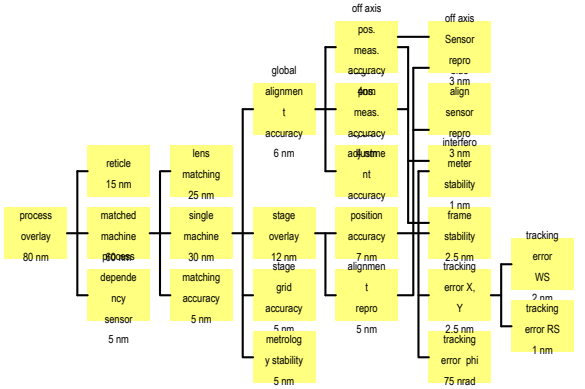
Attributes of a Method

- a goal
  - 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
- a decomposition in smaller steps

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	

- possible orders of taking these steps
- visualization(s) or representation(s)





Budget Based Design Decompositon and Order

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
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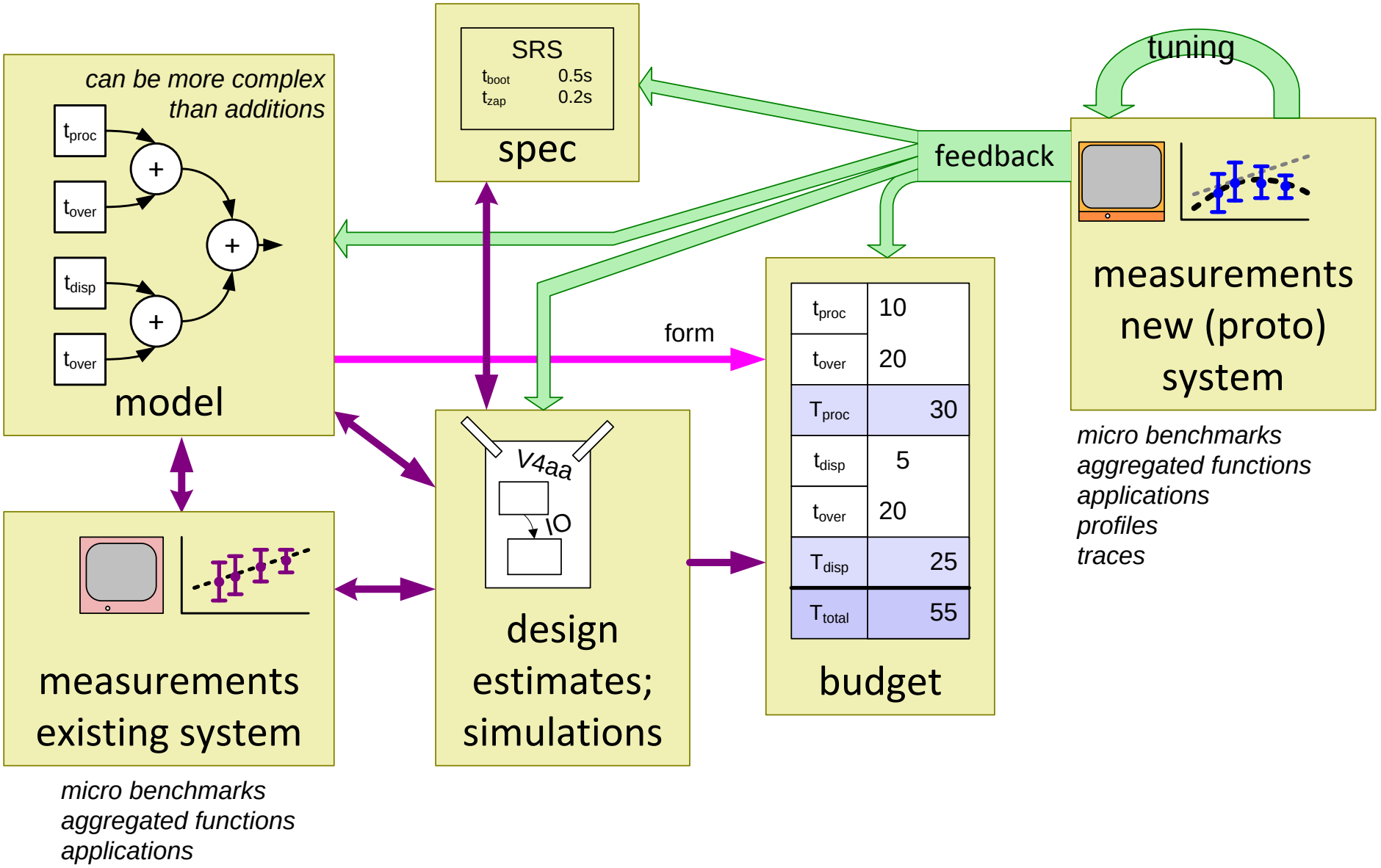
5 Iterate steps 1B to 4	

Visualization of Budget Based Design Flow



Conclusion

The design of Embedded systems

software intensive
large development teams
multi-disciplinary

> 1 Mloc
10..1000fte
software, electronics, physics, mechanics,...

will always be

Systems Architecting ~~is~~ an art

Skilled architects are scarce

will become even more complex:

> 10 Mloc

(10..100 suppliers)*(10..1000fte)

multi-system, multi-application, multi-site, multi-*

explicit know how facilitates more engineering,
supported by more system engineers

Failures, delays, non-performance, cost overruns, dissatified customers

plenty of research opportunities!

Research questions

- What are potential applications for budgets?
- What kind of budget is required?
- What is the decomposition to be used?
- How to manage margins?
- How to verify a budget?
- How to use and maintain a budget?
- Does it provide value when a budget is coupled to other design information?
- and many more...

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?