

# 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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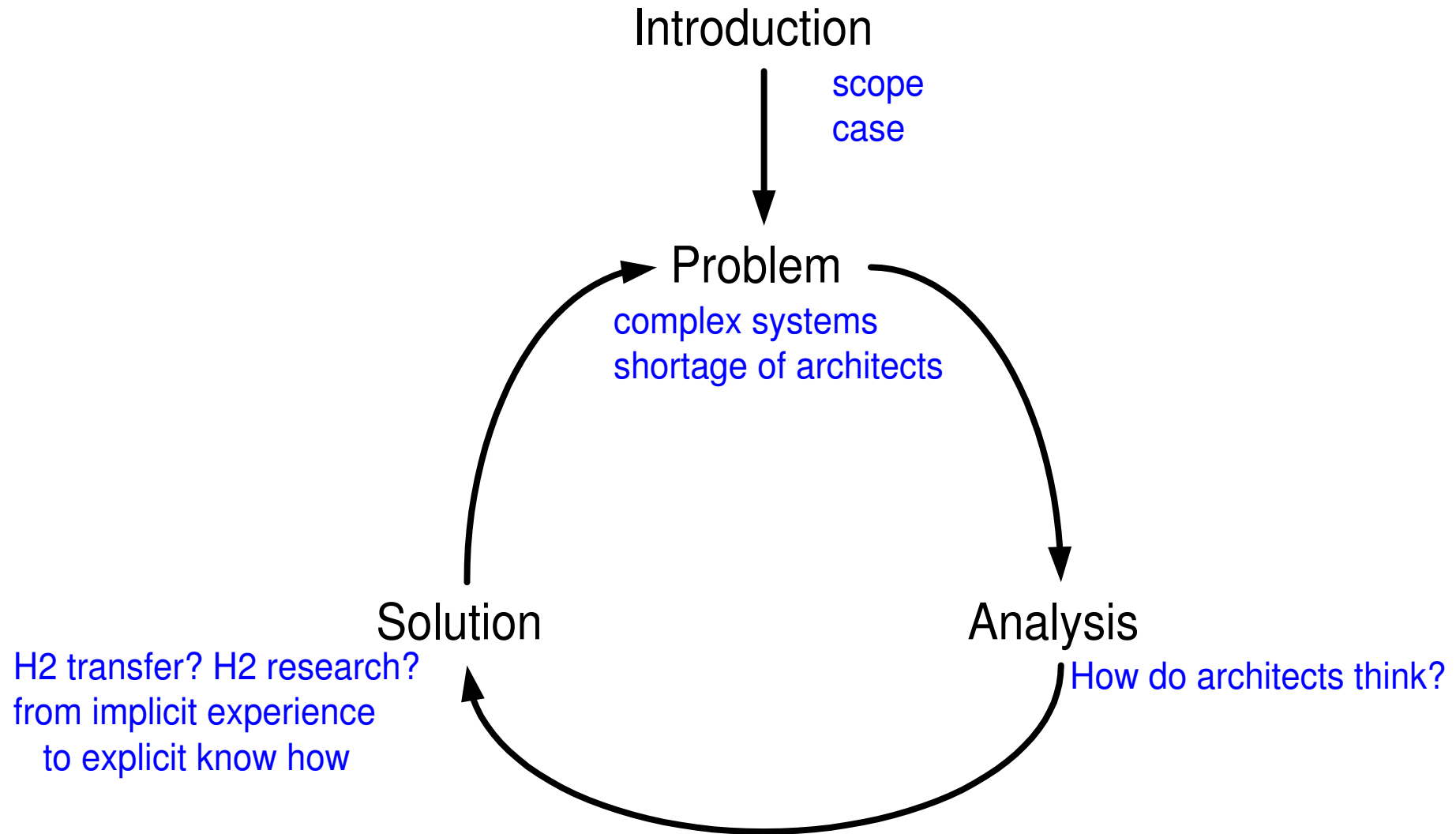
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logo  
TBD

# Outline of the Presentation

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# Embedded Systems; From Small to Large



chip



GSM



MRI scanner



cardio X-ray system



television



printer



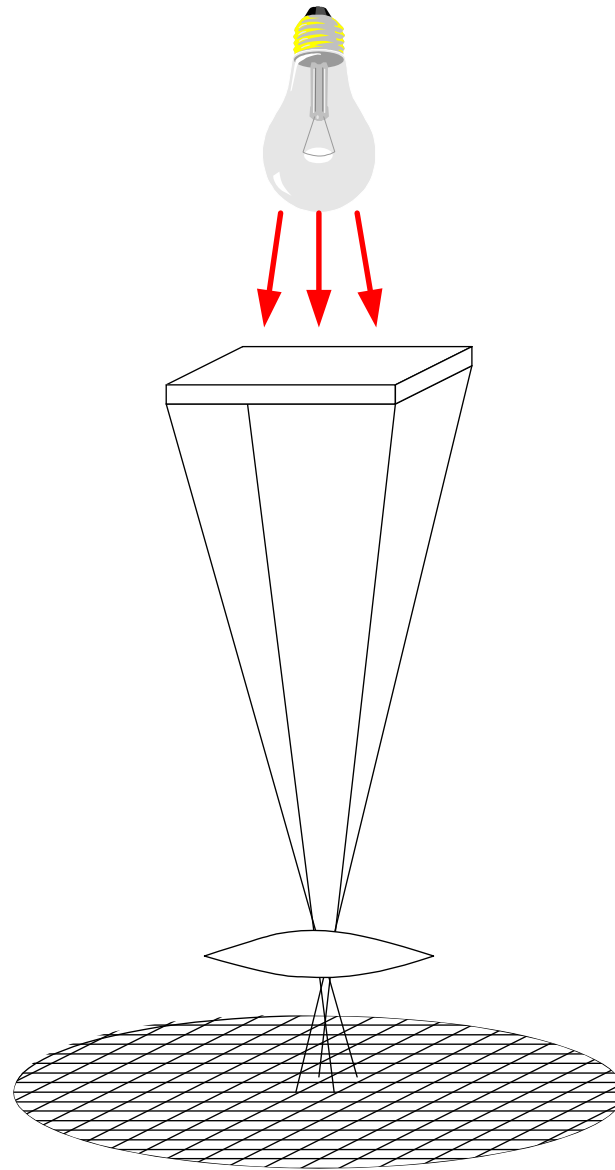
wafer stepper

# Twinscan AT1100



# What is a Waferstepper

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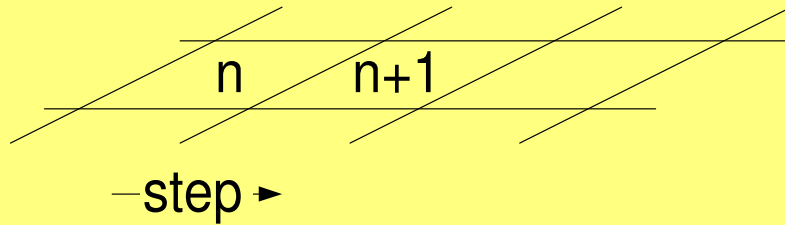
source

reticle

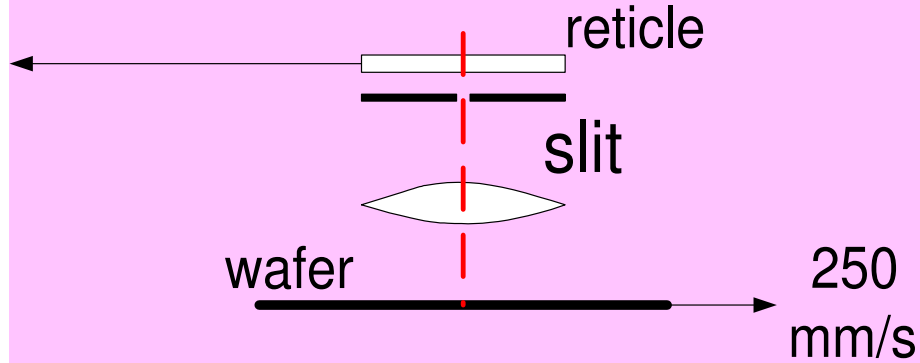
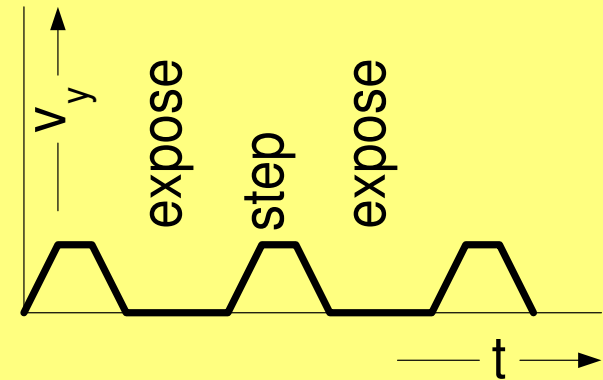
lens

wafer

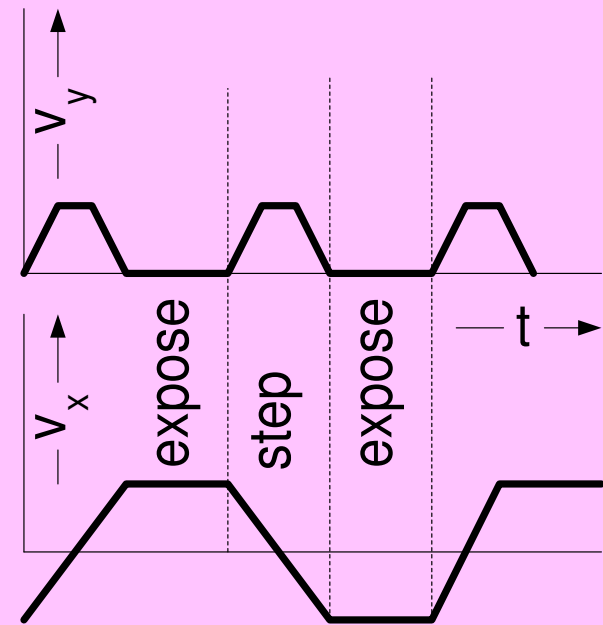
# From stepping to scanning



**stepper:** static exposure of field

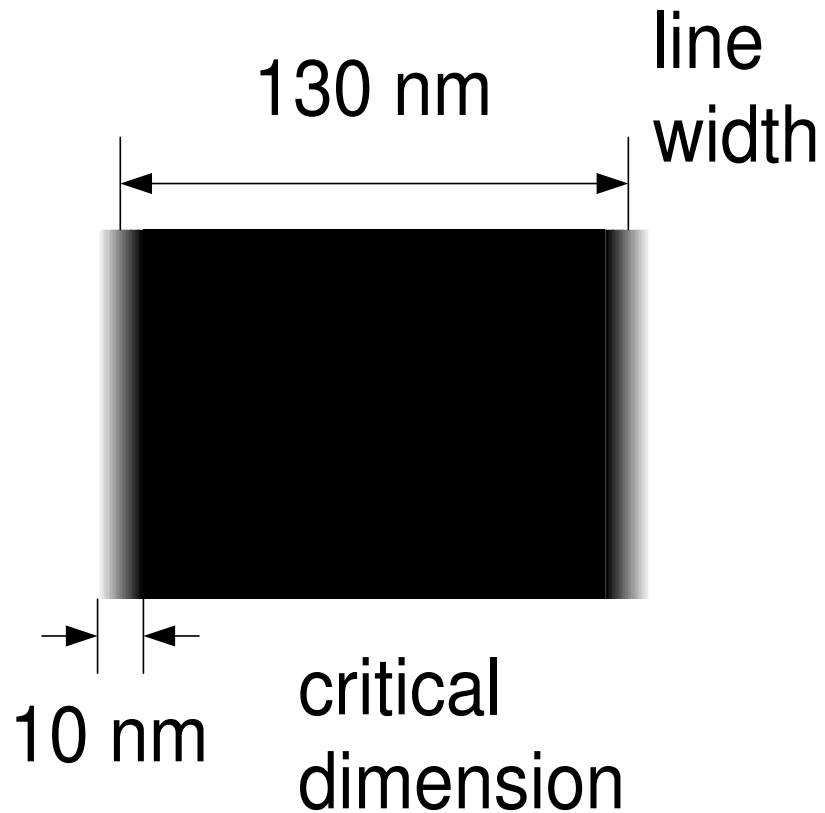


**scanner:** dynamic exposure through slit

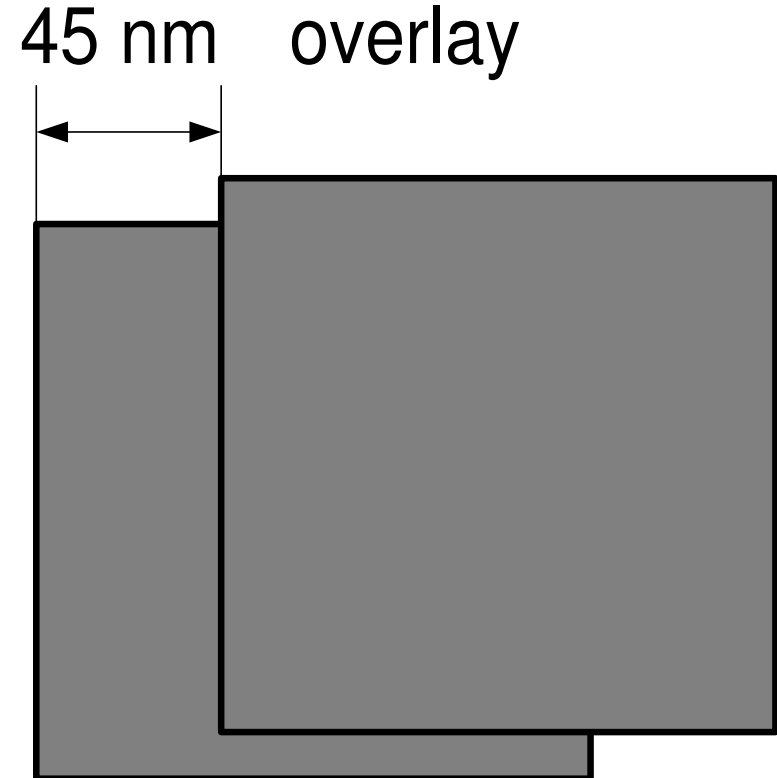


# Key specifications waferstepper (2001)

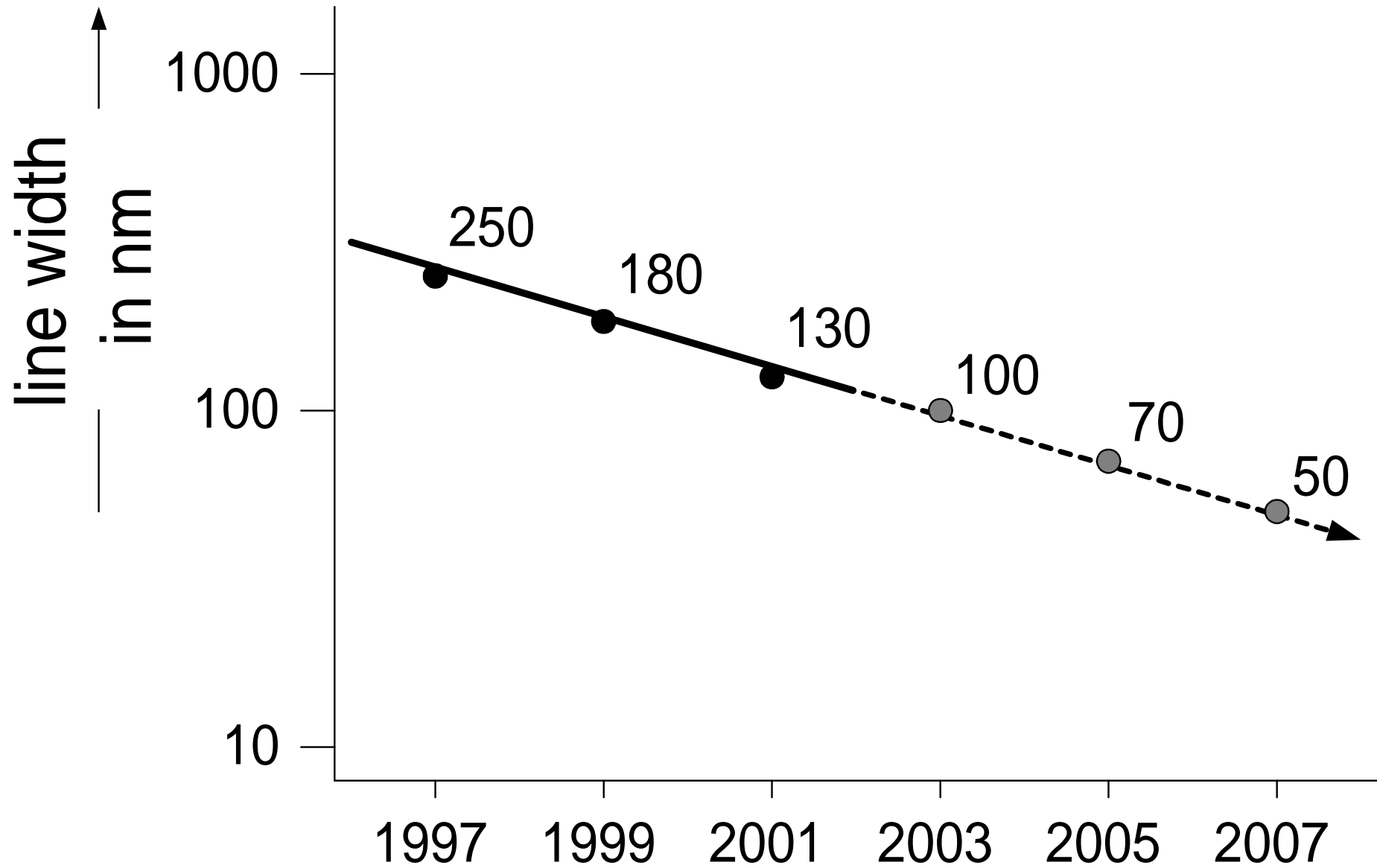
imaging



alignment



# Moore's law



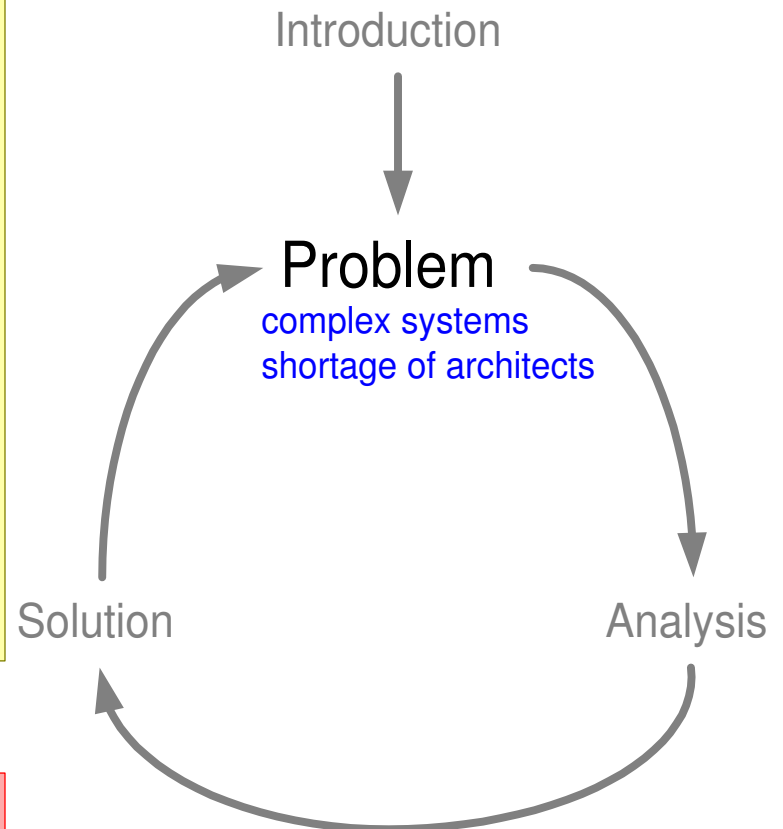
# Problem Statement

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

Systems Architecting is an art

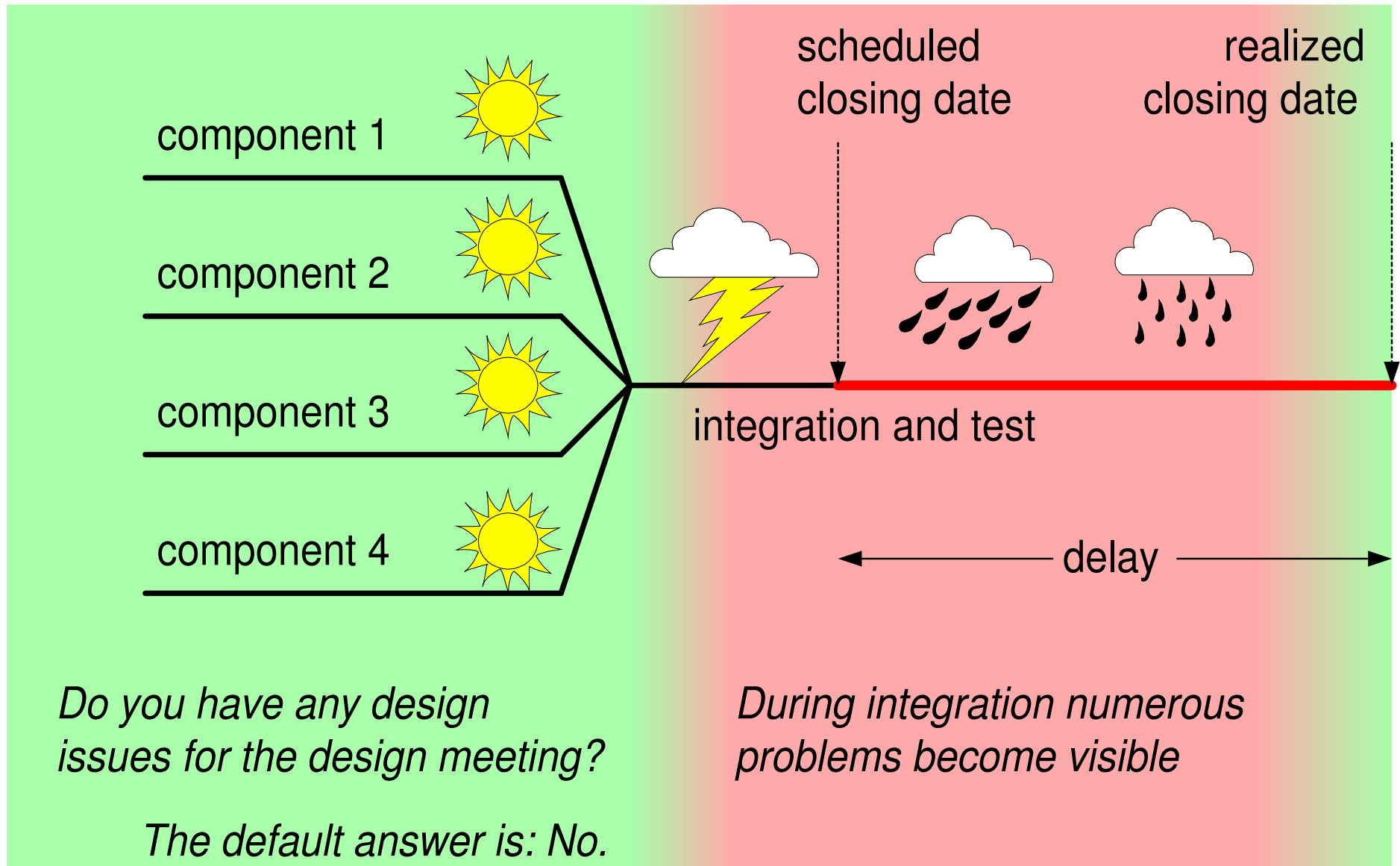
Skilled architects are scarce

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

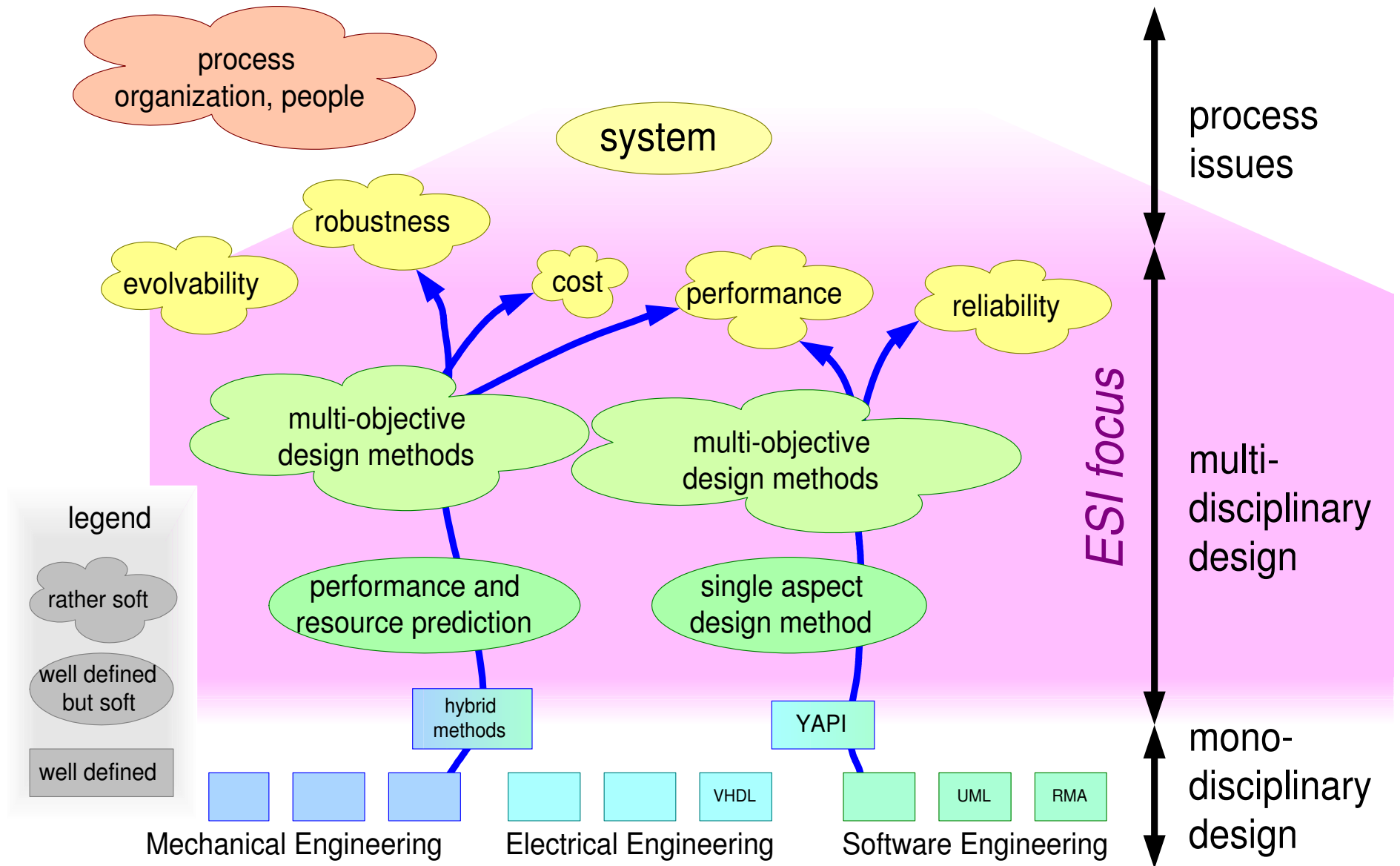


' Eberhardt Rechtin and MarkW. Maier.  
*The Art of Systems Architecting.*

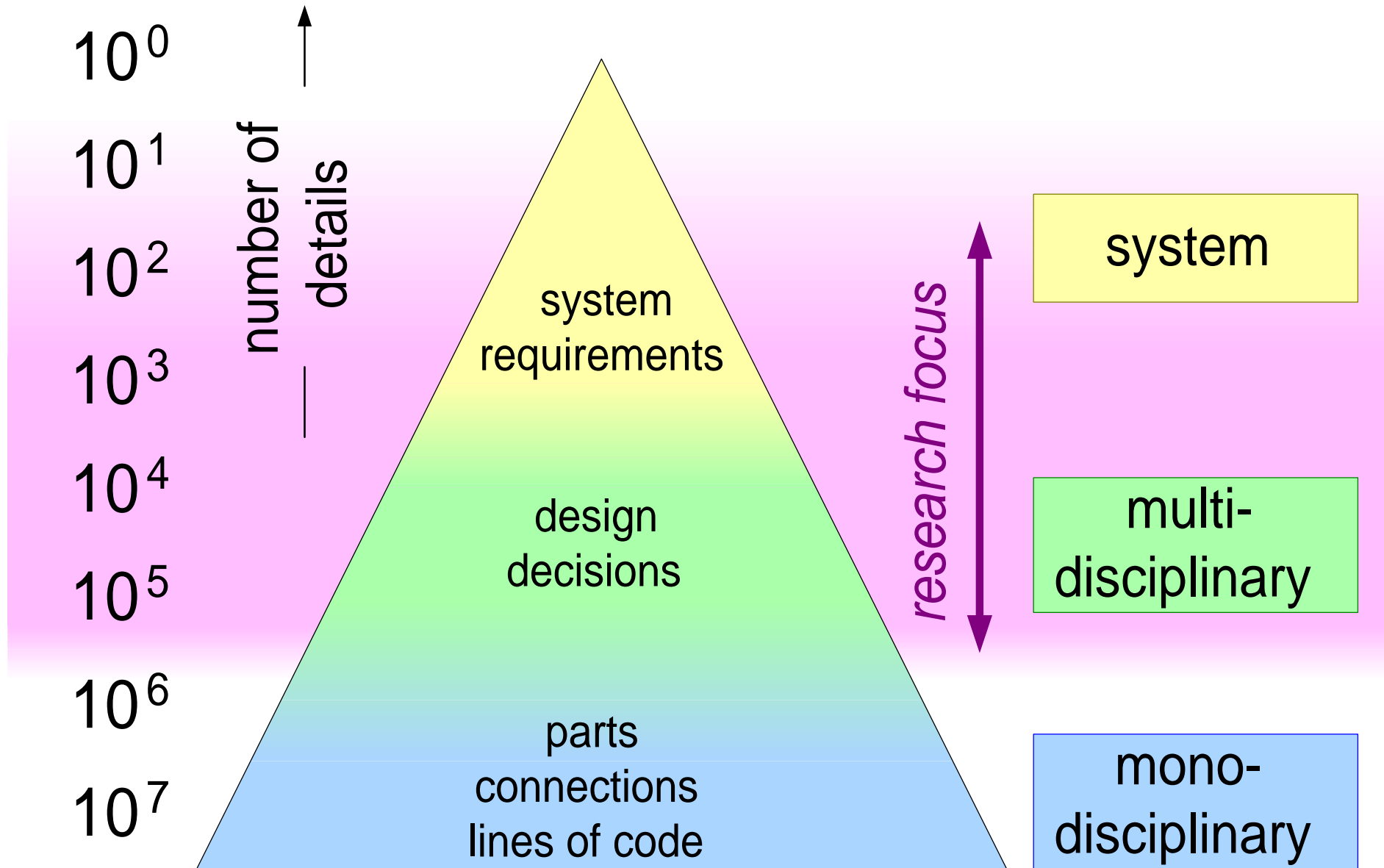
# Symptom: Delays appear during Integration



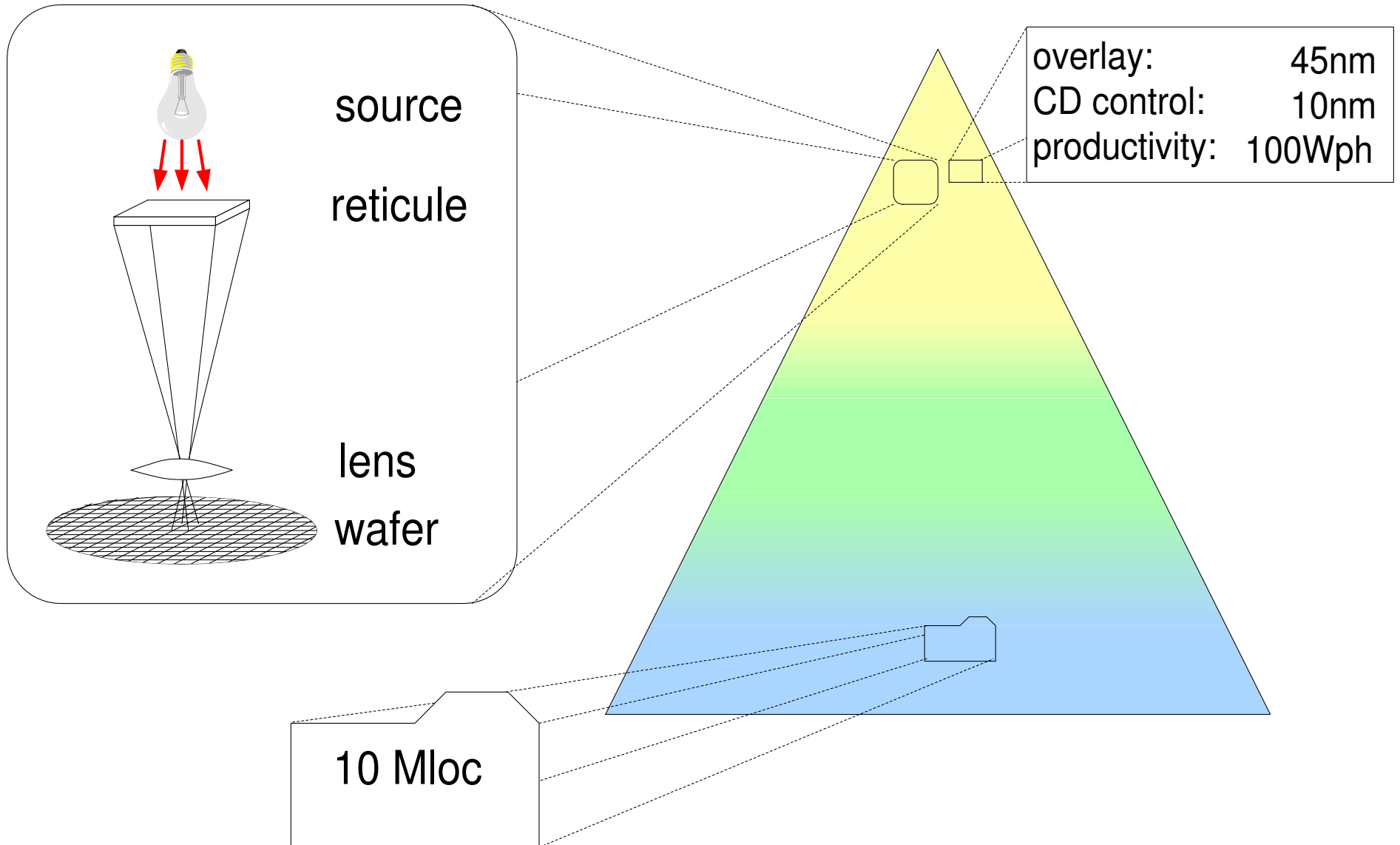
# From Mono-Disciplinary to System

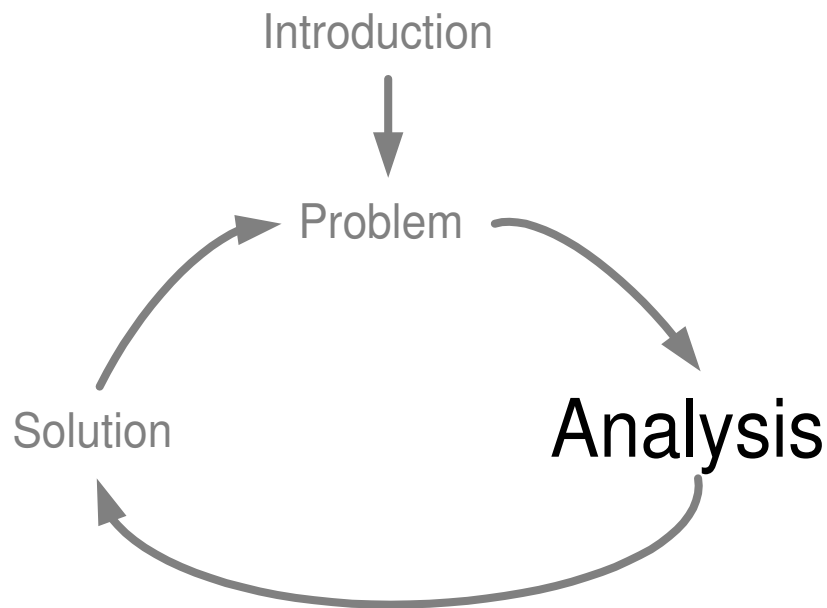


# Exponential Pyramid, from requirement to bolts and nuts



# How to go from System Level to Detailed Designs?





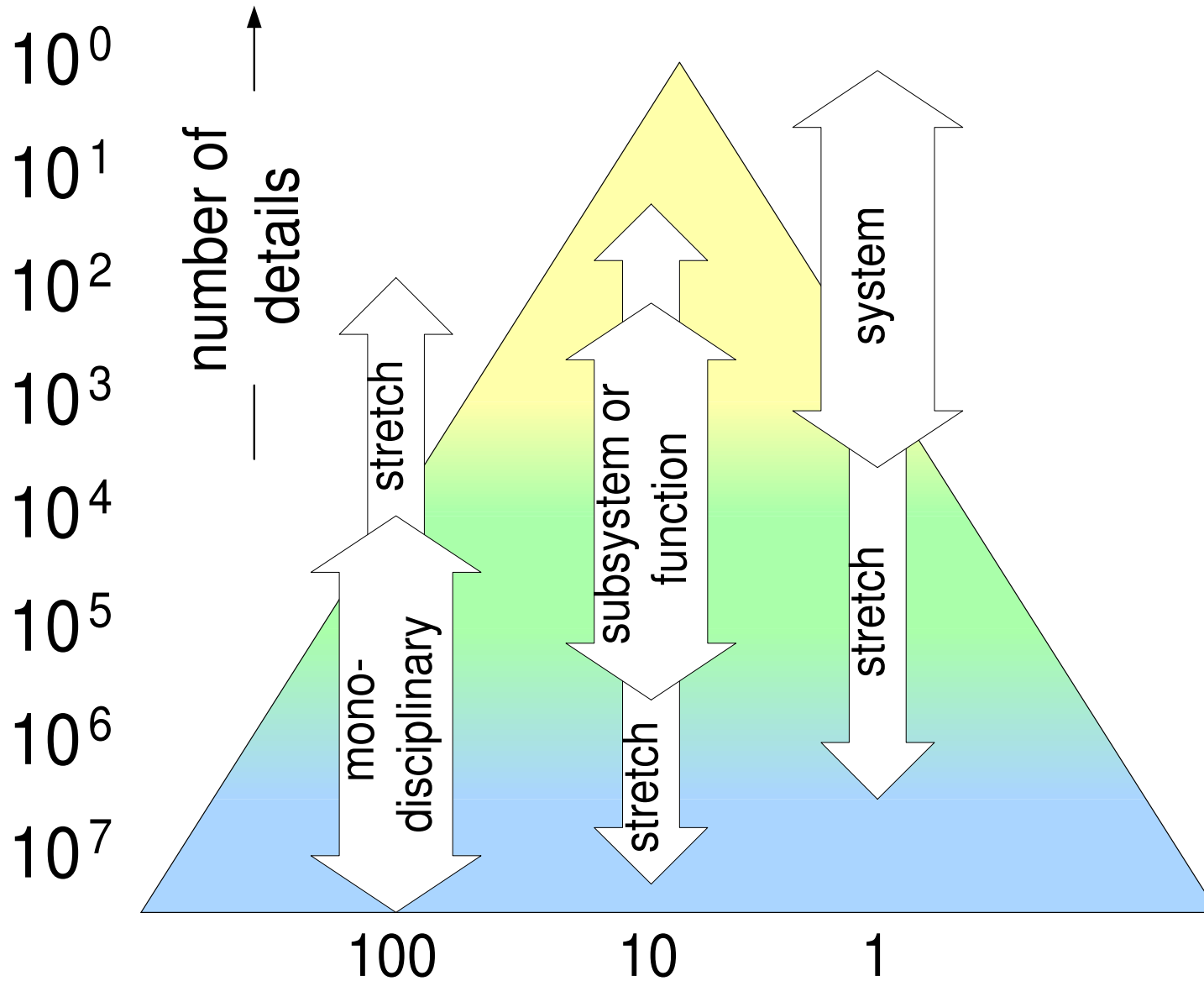
How to cope with dynamic range?

multiple people  
overlap  
stretch

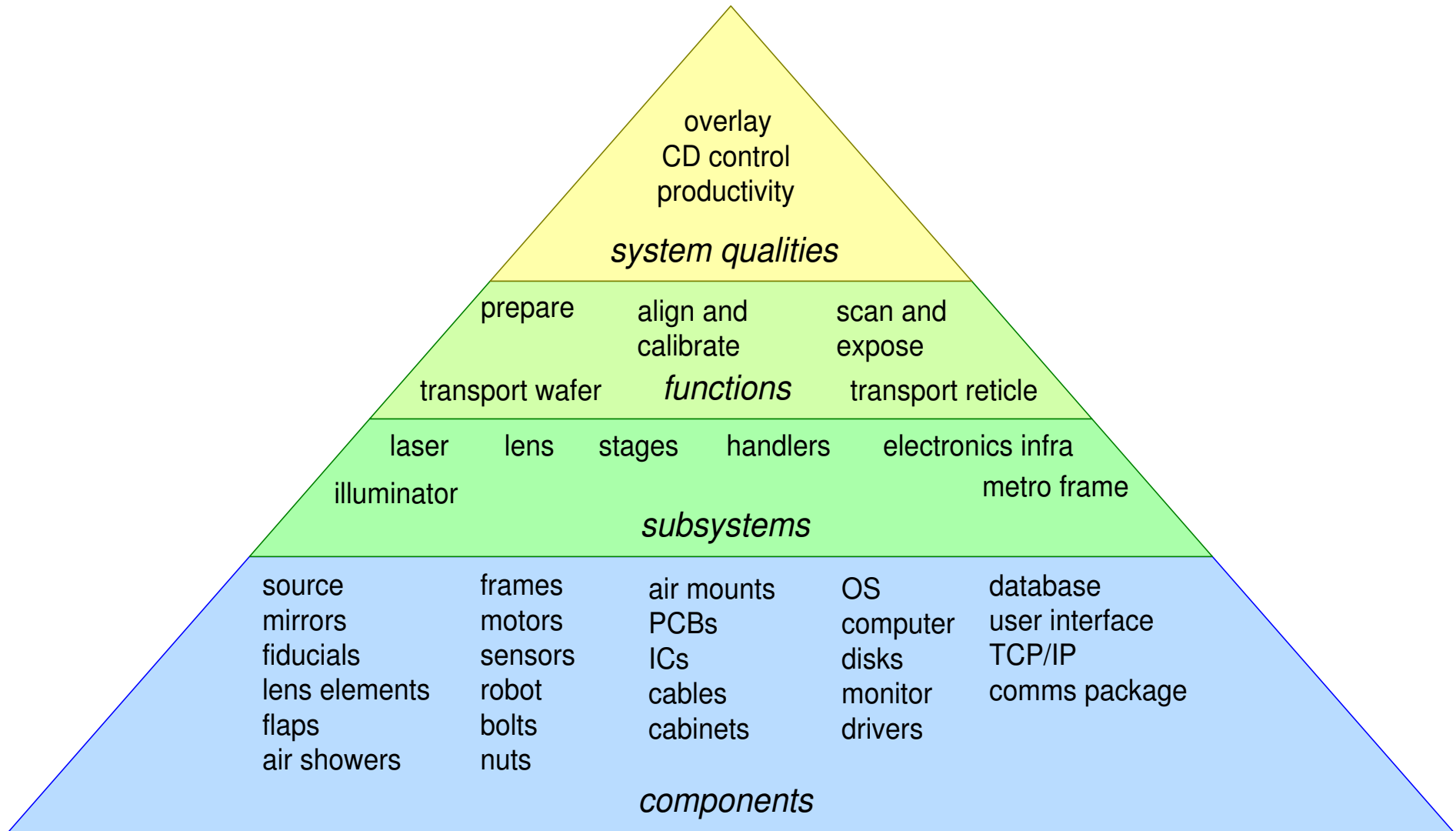
How do skilled architects work?

viewpoint hopping  
fast iterations  
from vague to tangible  
integrating

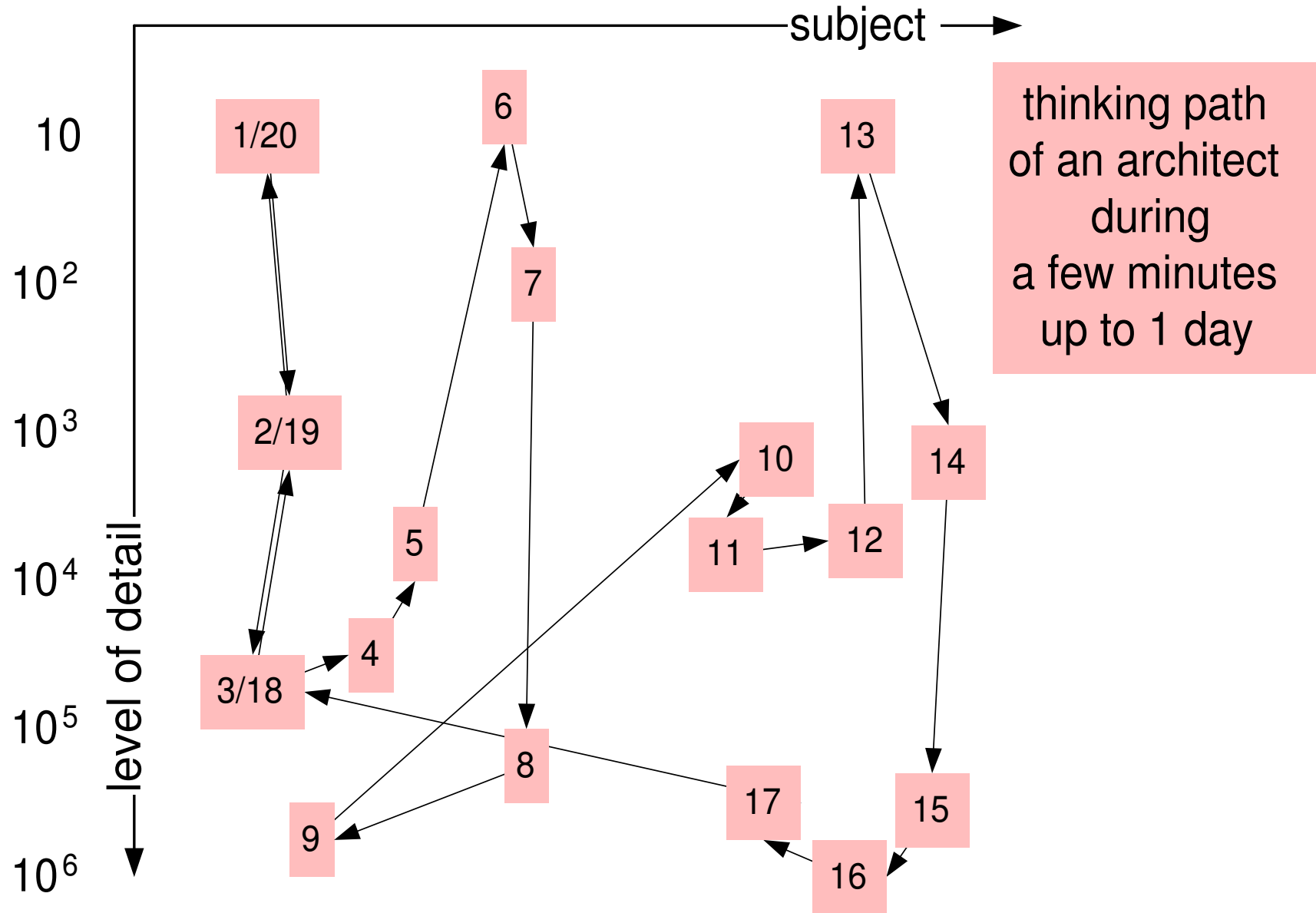
# Major Bottleneck: Mental Dynamic Range



# 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:*

**wafersteppers**  
**health care**

electronics infrastructure projects

**document handling**

consumer electronics

semiconductors

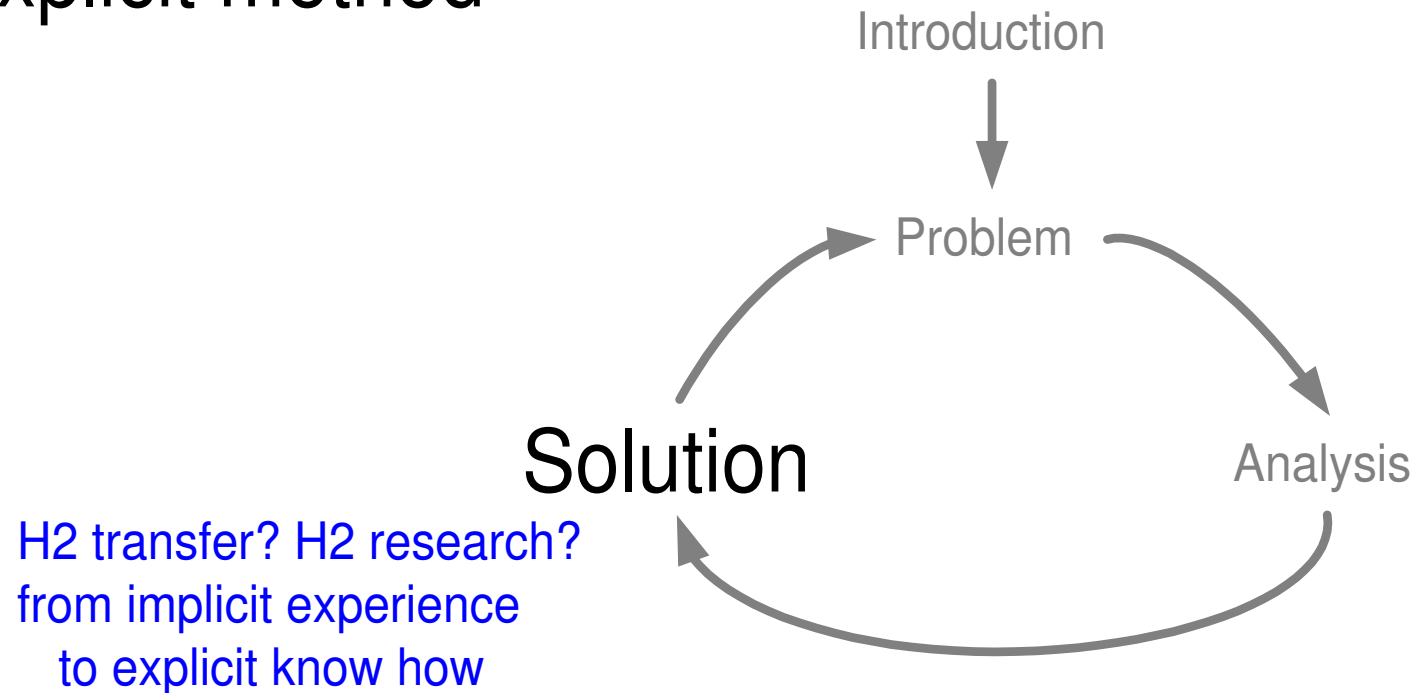
**the budget-based design  
method will be discussed  
as applied in wafersteppers,  
health care, and document handling**

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

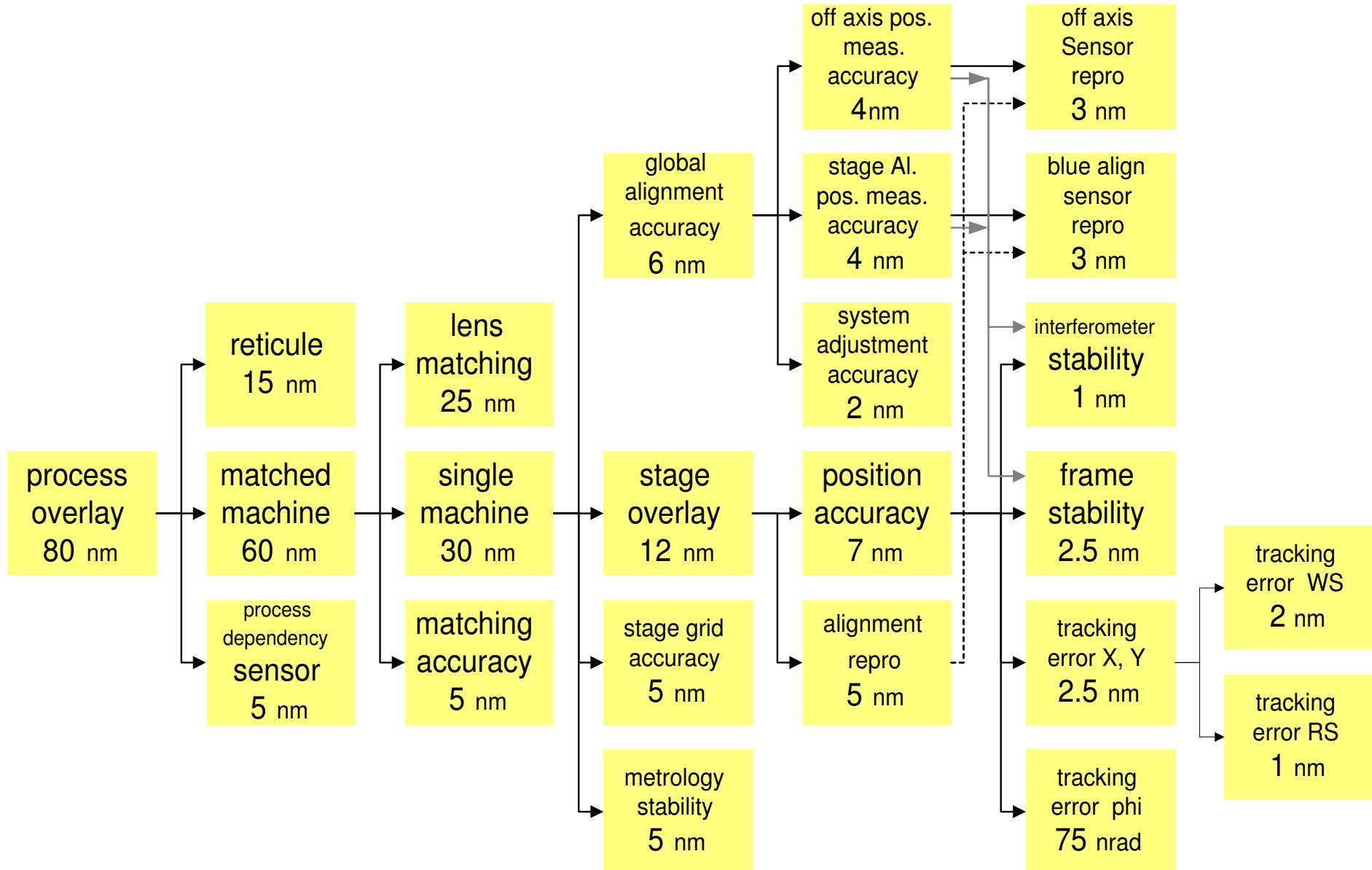
# Solution

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



# Budgets Applied on Waferstepper Overlay

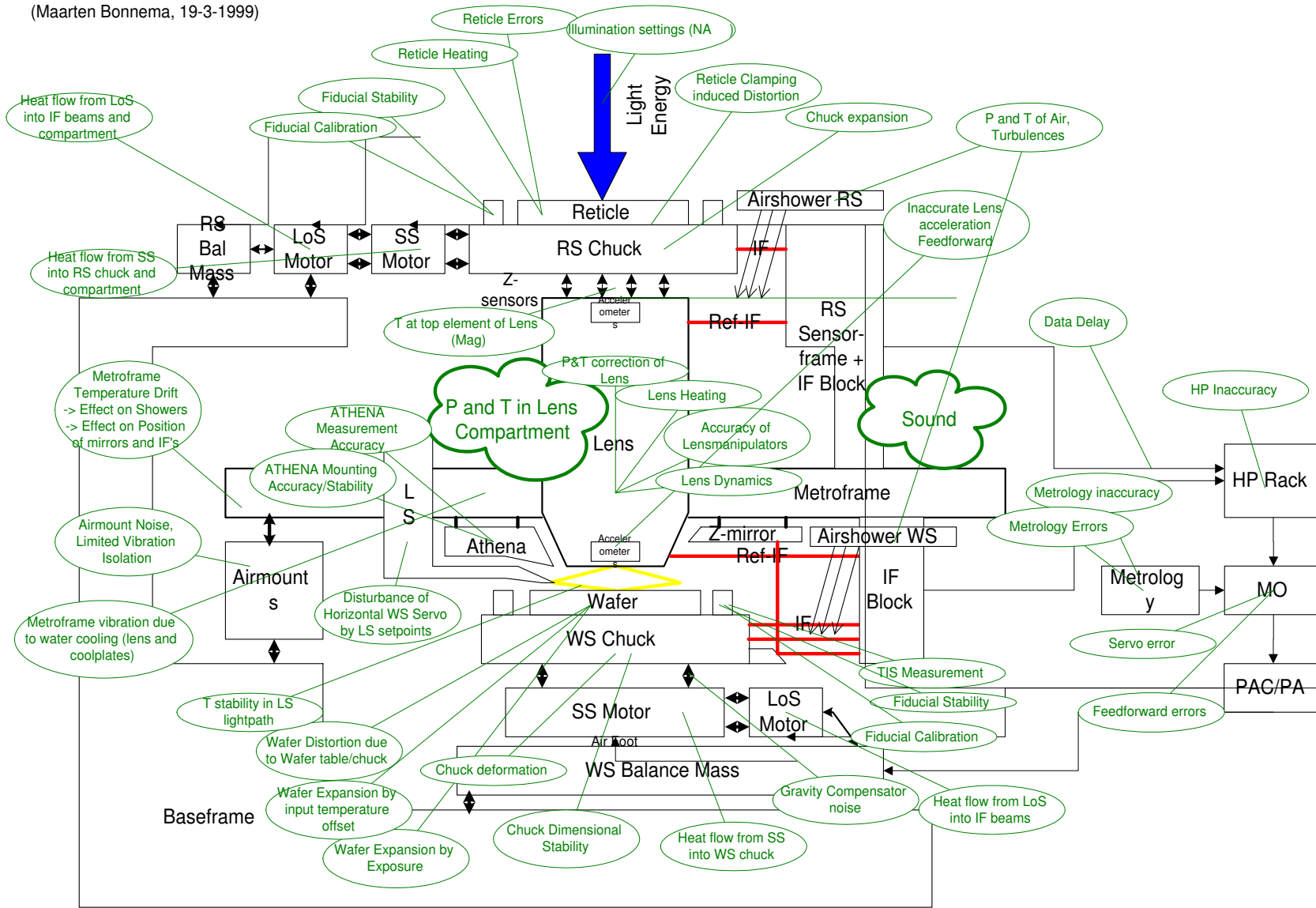


# Many Details are Input to the Budget

## Overlay Influence Diagram.

(Maarten Bonnema, 19-3-1999)

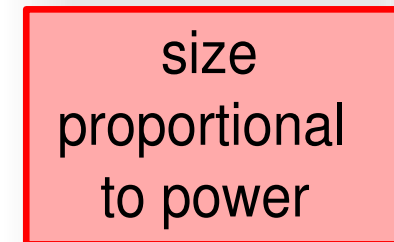
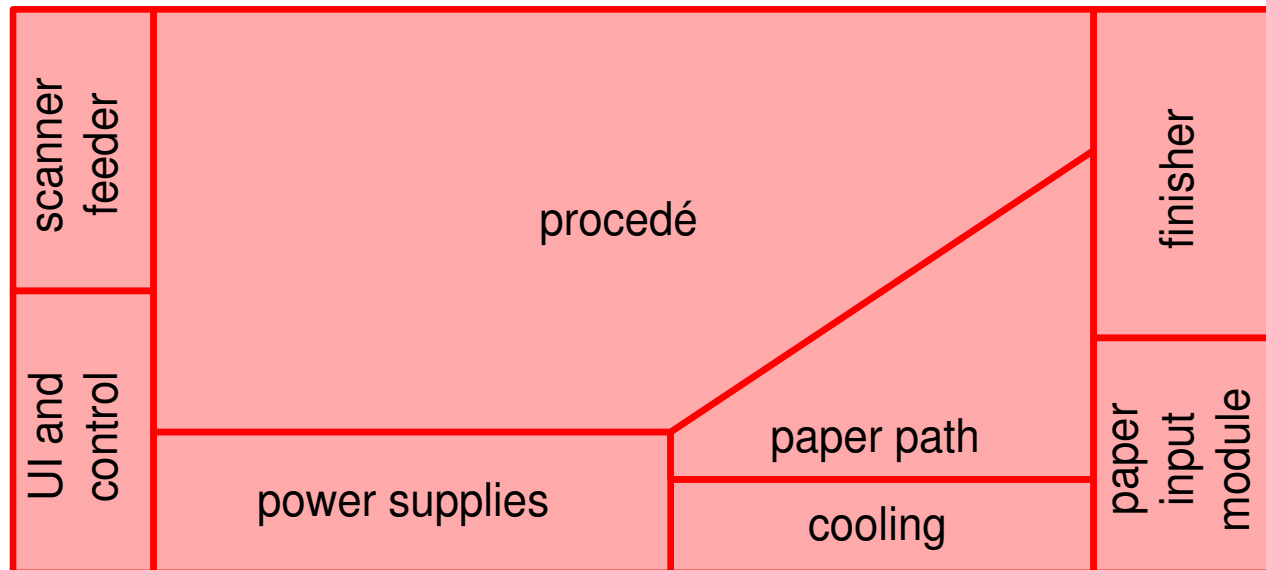
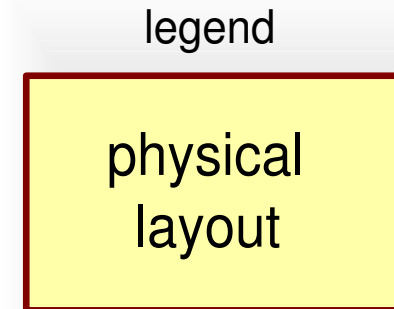
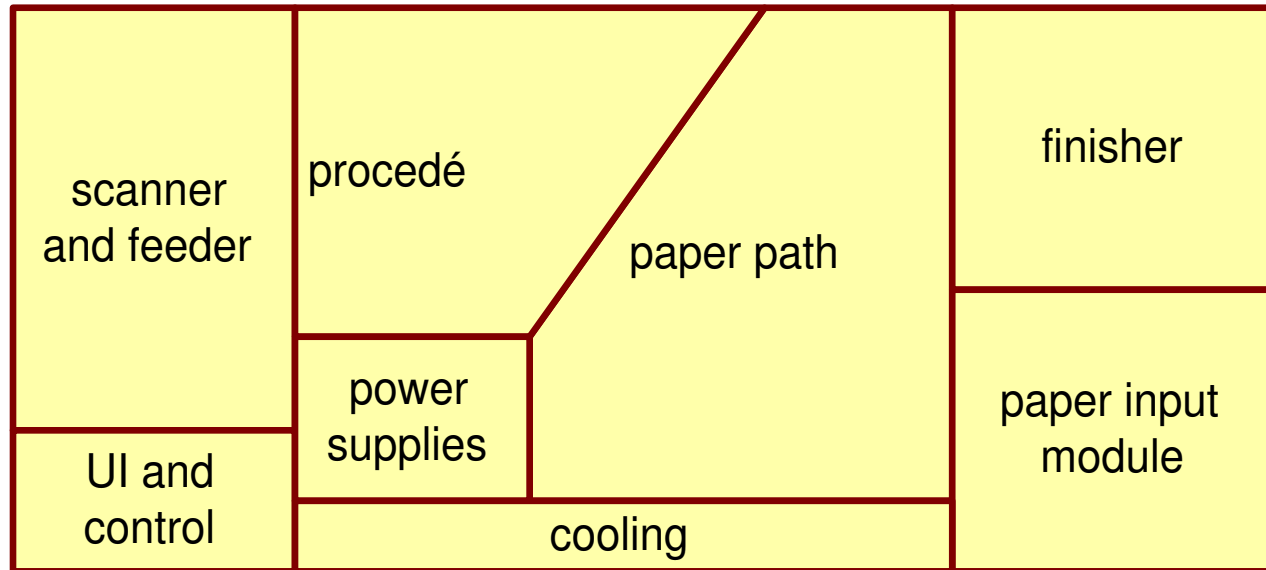
□ : Fiducial



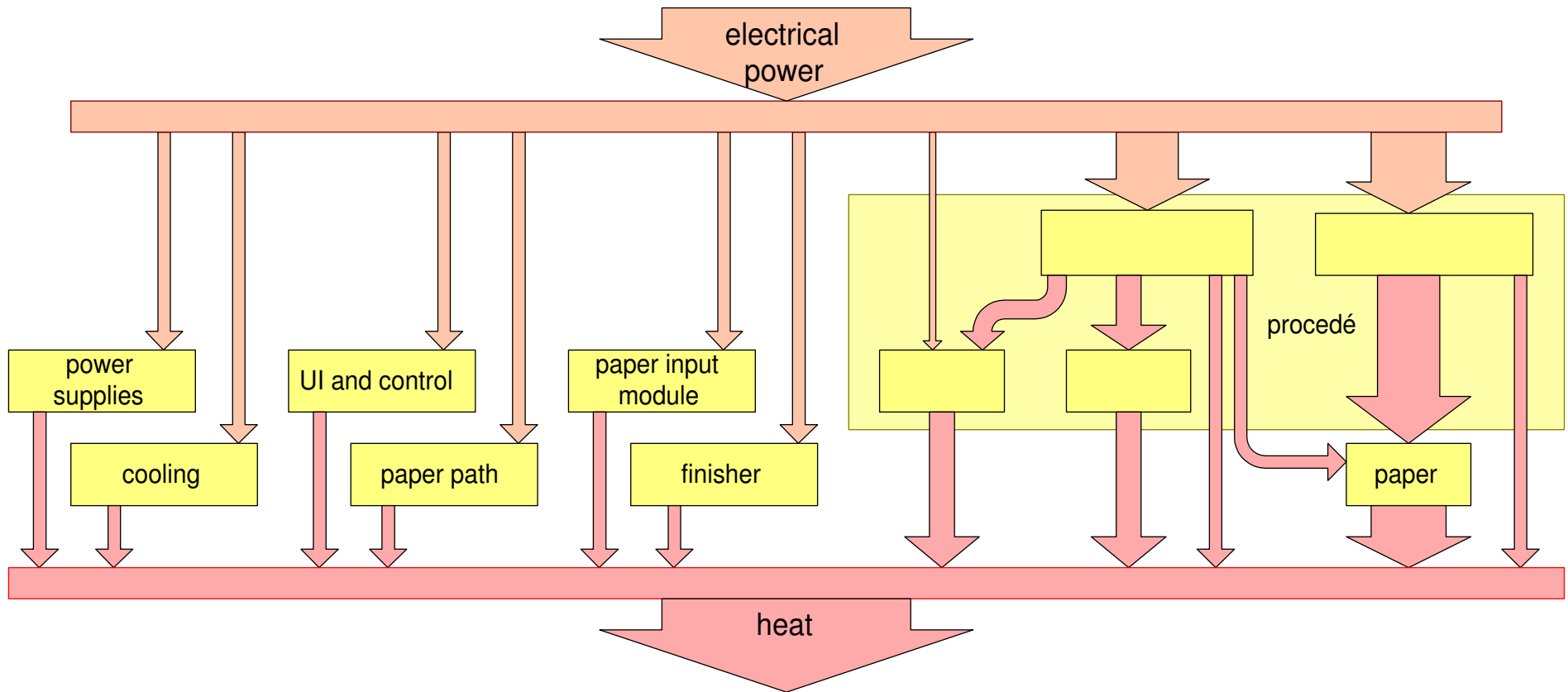
# Budgets Applied on Medical Workstation Memory Use

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

# Power Budget Visualization for Document Handler



# Alternative Power Visualization



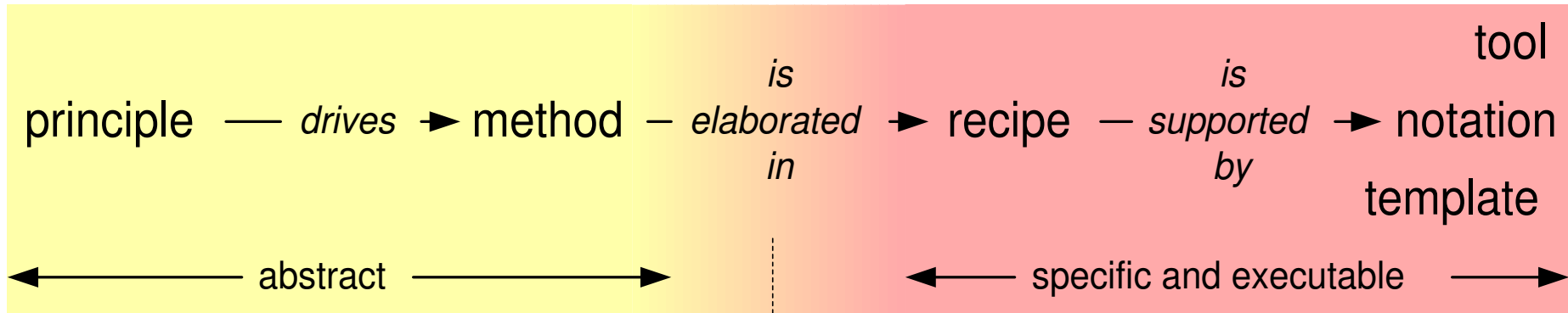
# So, What are the Open Questions?

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- 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

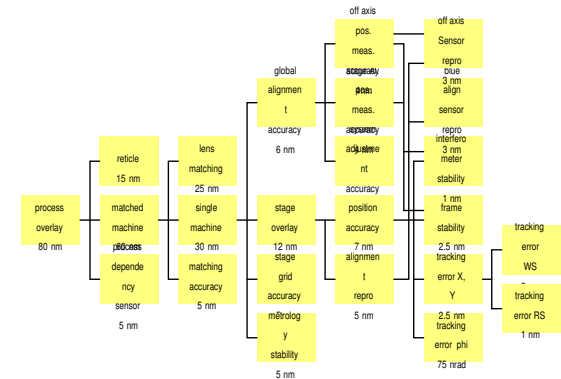
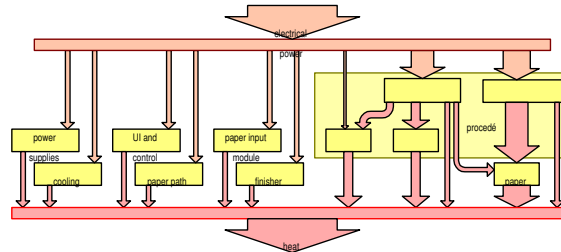
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# Attributes of a Method

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

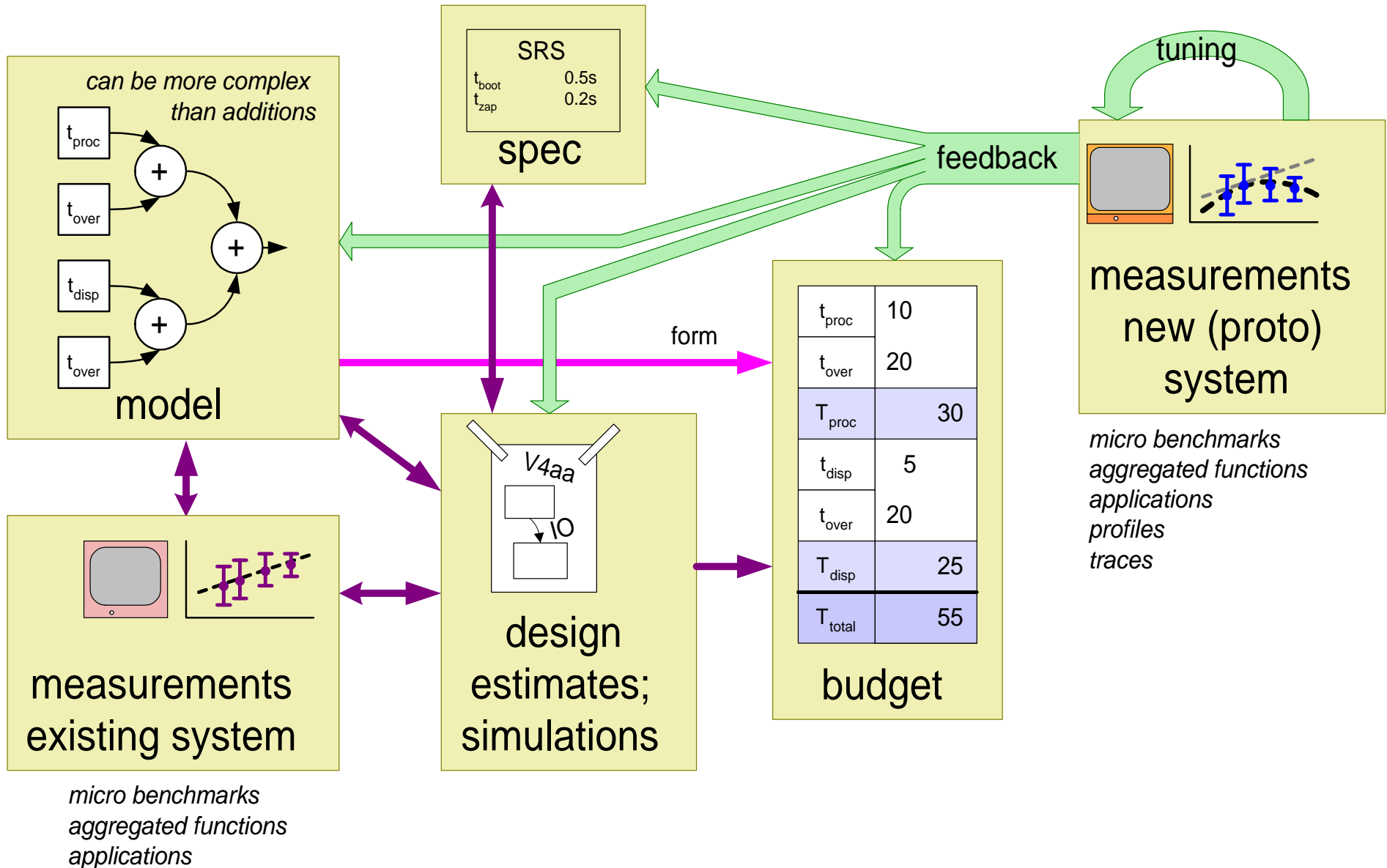
step	example
1A measure old systems	micro-benchmarks, aggregated functions, applications
1B model the performance starting with old systems	flow model and analytical model
1C determine requirements for new system	response time or throughput
2 make a design for the new system	explore design space, estimate 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	



# Budget Based Design Decomposition 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
4 measure prototypes and new system	micro-benchmarks, aggregated functions, applications profiles, traces
5 Iterate steps 1B to 4	

# Visualization of Budget Based Design Flow



# Conclusion

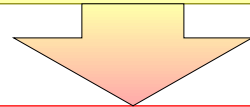
## The design of Embedded systems

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

will always be

Systems Architecting ~~is~~ an art

Skilled architects are scarce

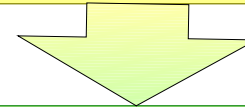


Failures, delays, non-performance,  
cost overruns, dissatisfied customers

*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



plenty of research opportunities!

# Research questions

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- 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

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- 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?

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static

dynamic

typical case

worst case

global

detailed

approximate

accurate

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