

# From Autonomous Subsystems to Integrated System

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## Abstract

Systems evolve from mostly mechanical or physical devices into multi-disciplinary integrated systems. This evolution takes years or decades. The evolution occurs simultaneously with changes in the markets and in the organization. We describe this evolution and illustrate it with a X-ray systems and wafersteppers.

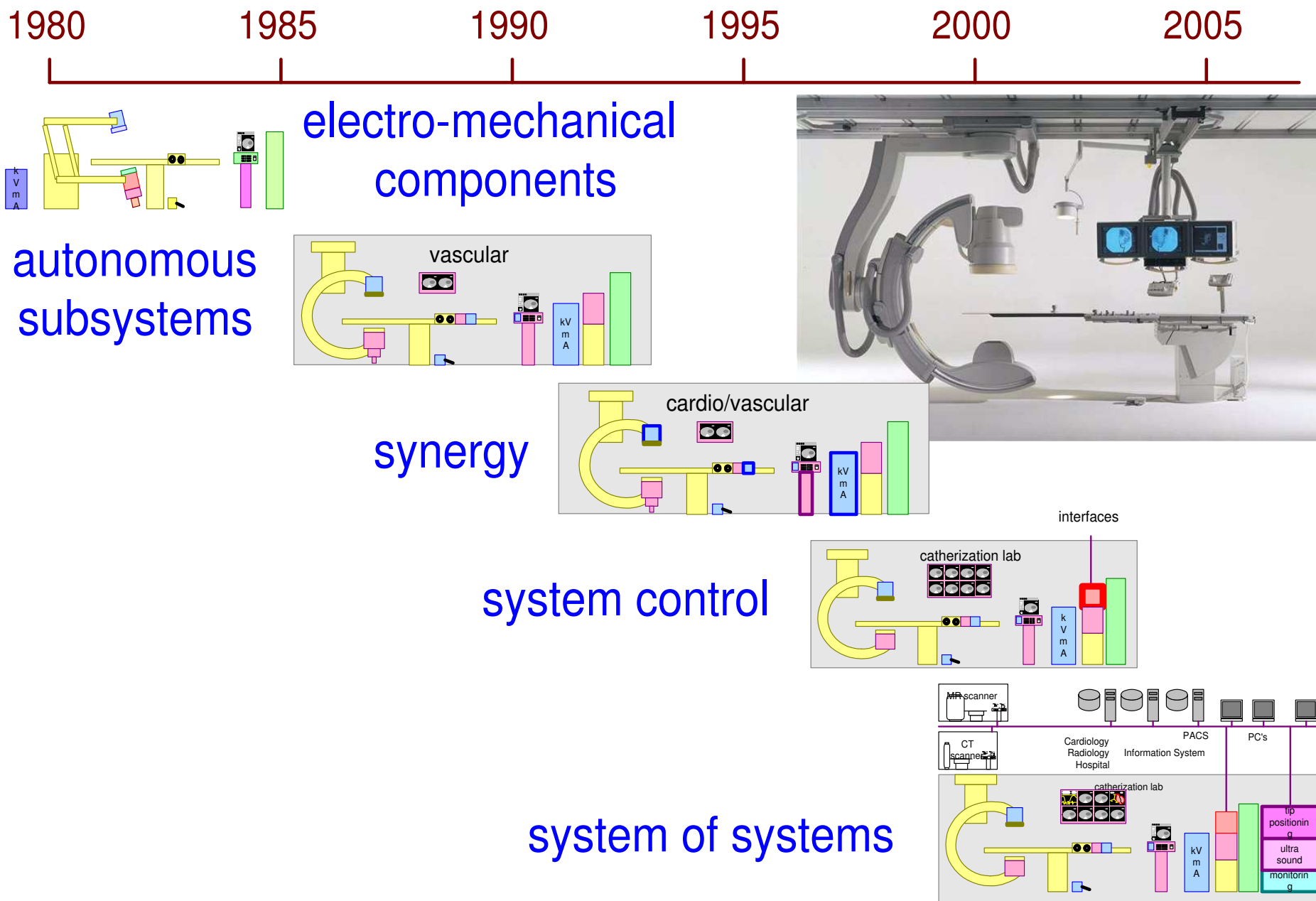
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logo  
TBD

# Evolution of X-ray Systems



# Diagnostic X-ray system 1980

..~1980

many independent modules most Philips, some 3<sup>rd</sup> party

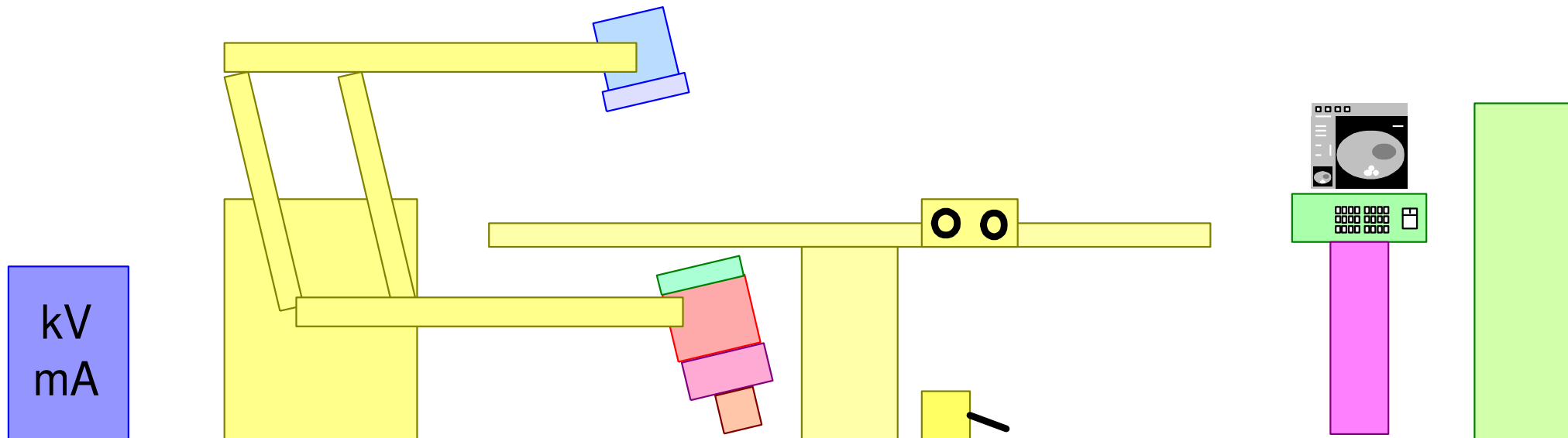
sales: all configurations are possible

system integration (SI) in factory

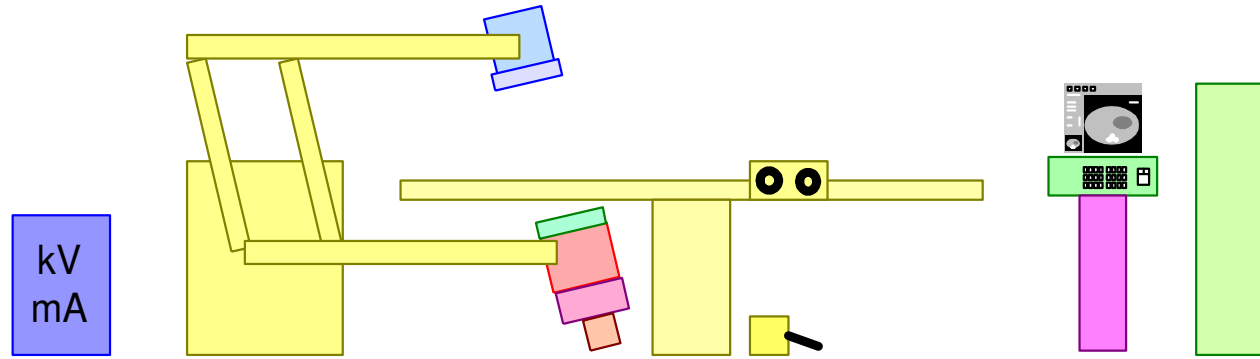
many adaption boxes

SI is mostly electro mechanical

innovation elapsed time many years (f.i., 10 years for new imaging chain)



# Organization in 1980



*innovation  
departments*

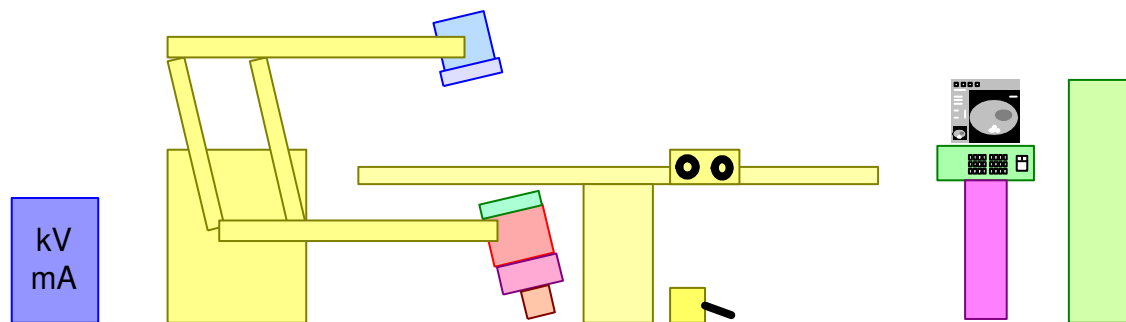
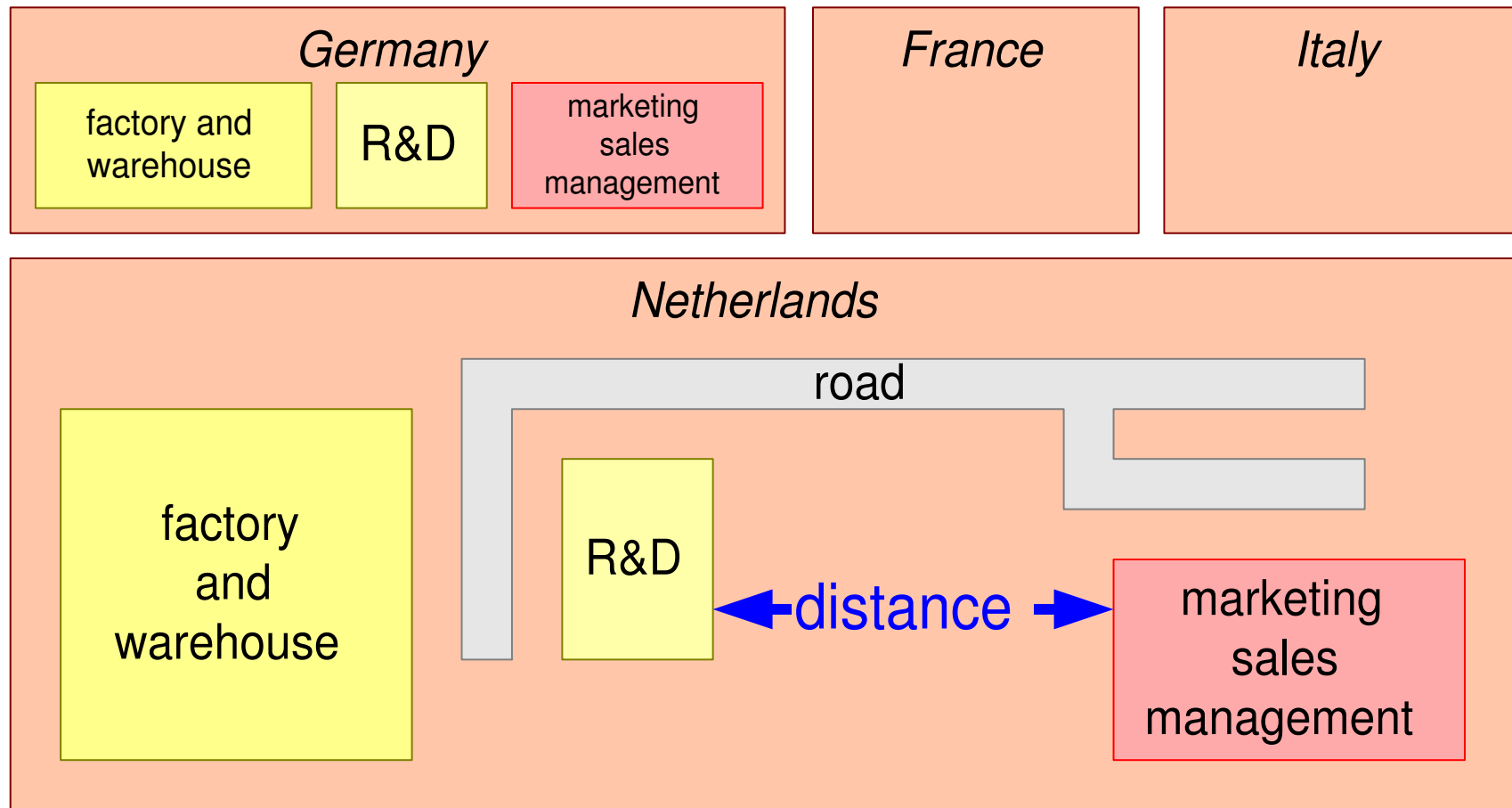
Roentgen  
Electronics  
Laboratory

Mechanical  
Electronics  
Laboratory

Physics  
Technical  
Laboratory

*facilitating departments:* drawing office; construction office; workshops

# Geographical locations in 1980



# Staff in 1980

small teams

3 key persons:

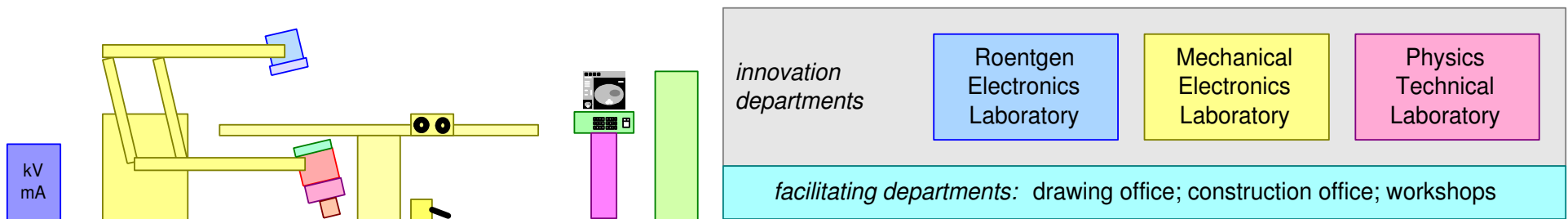
application

senior designer

cardiologist (outside Philips)

application and domain technology implicit in most staff

staffing mostly domain technology driven



# Systems 1985..1995

..~1985

autonomous subsystems:

Geo

Acquisition

Imaging

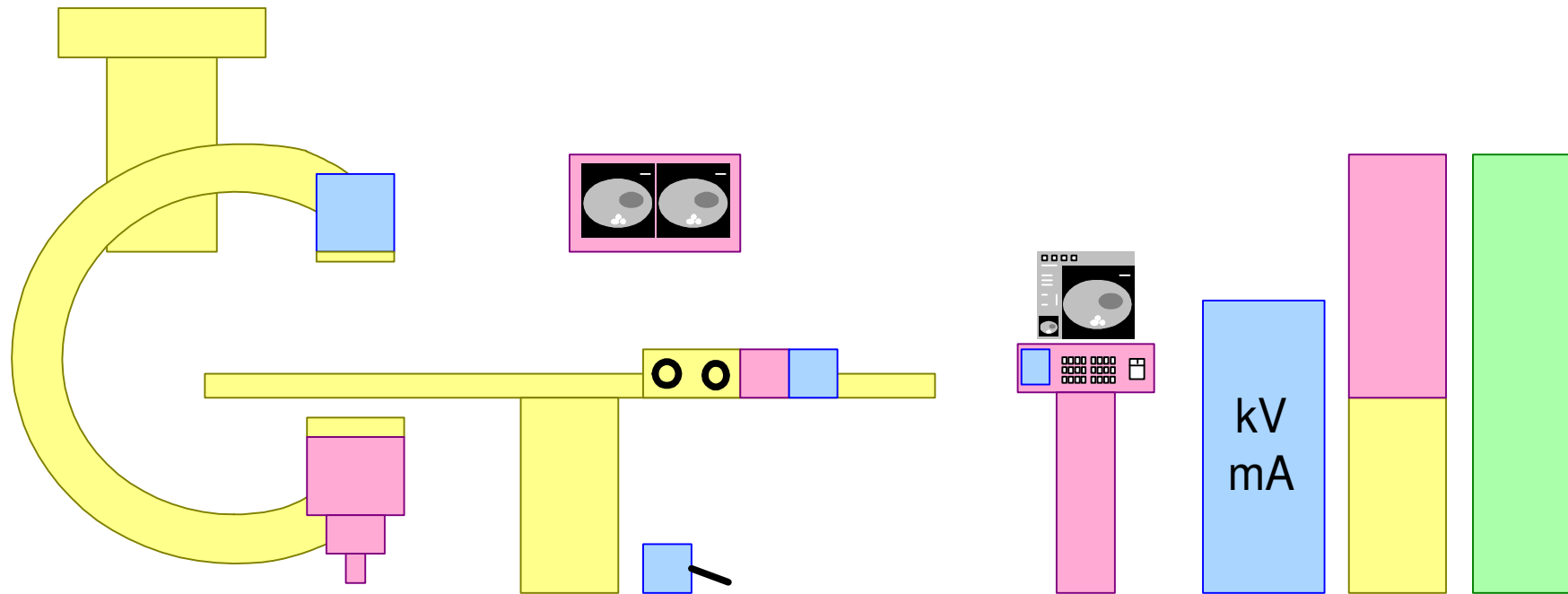
X-ray generation

sales: preferred configurations; arbitrary configurations are more expensive  
system integration (SI) in R&D

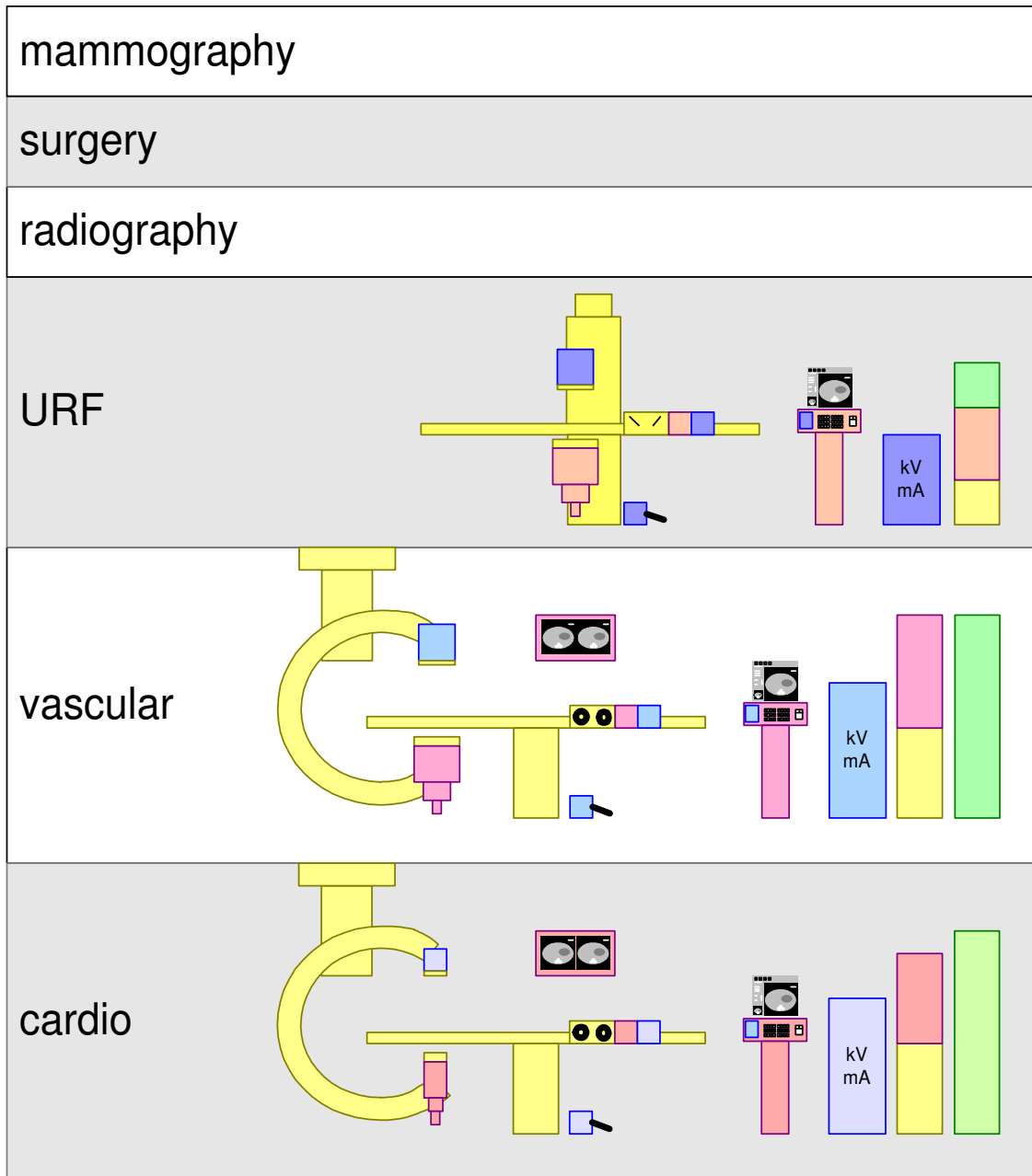
SW in all subsystems

SI is electro mechanical *and configuration parameters*

innovation elapsed time several years (f.i., 2 years for digital imaging chain)

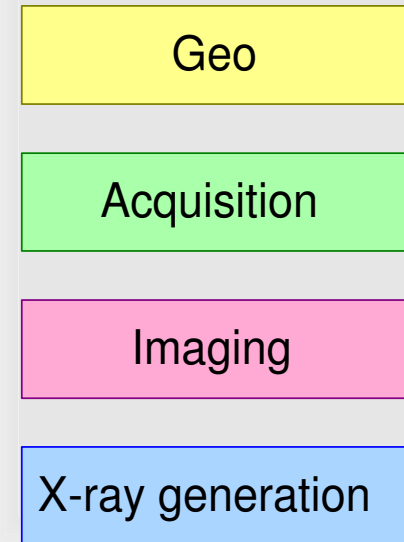


# Organization in 1985: Product/Business Oriented



most products:  
 successful  
 application oriented  
 little synergy or commonality  
 struggling with software

legend





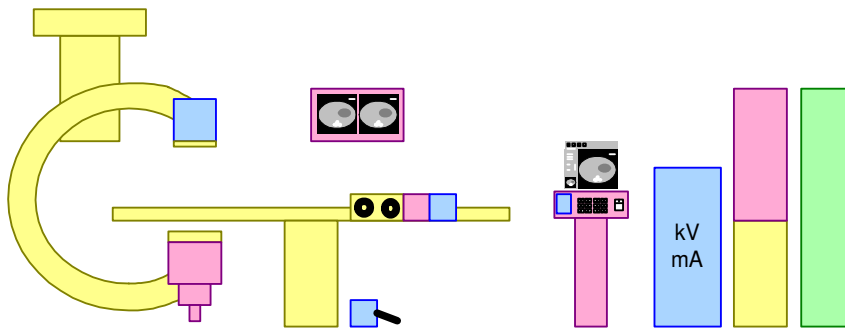
medium sized teams

strong subsystem focus

software depends on few good SW engineers  
(often with HW background)

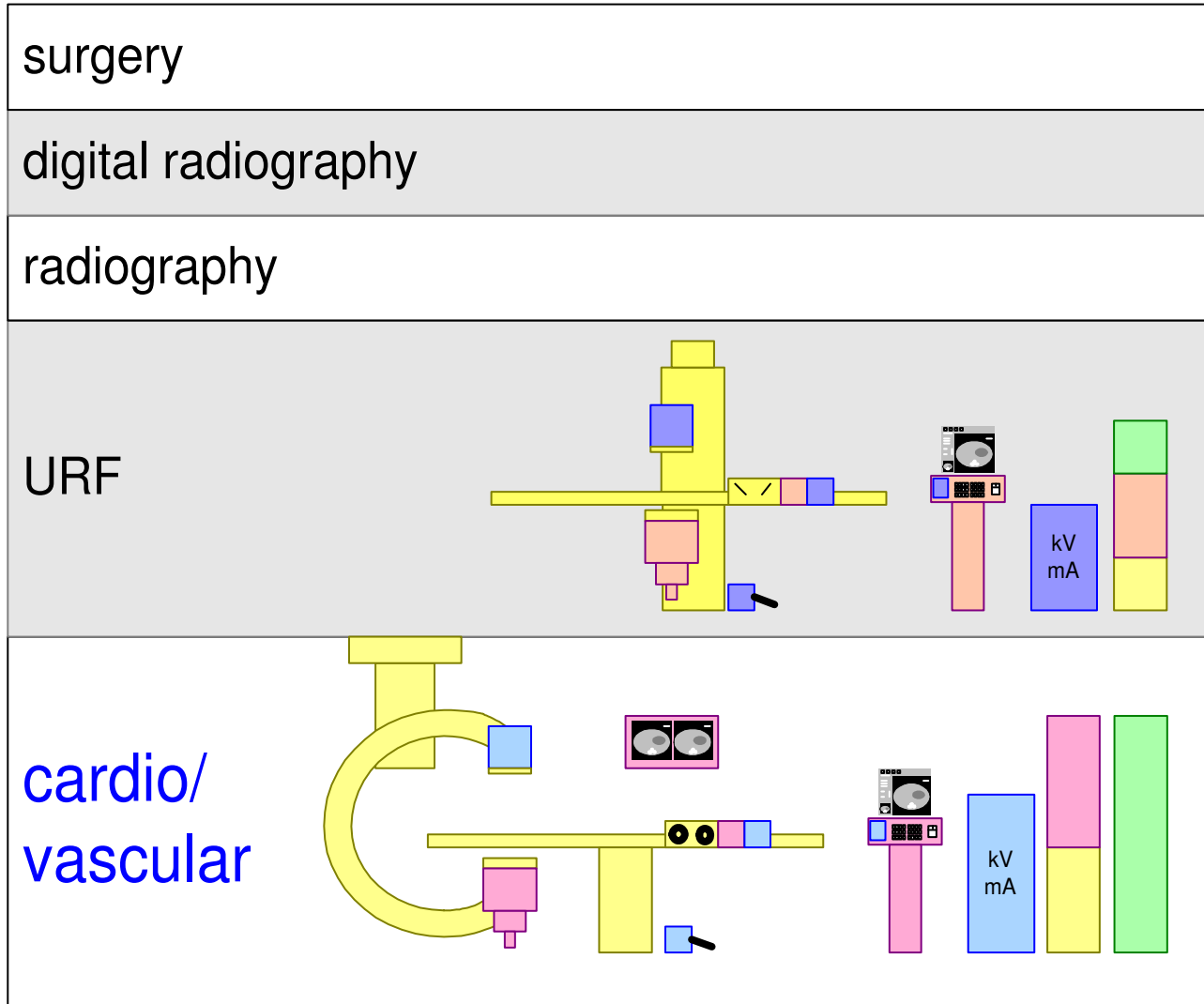
project leader is also system designer

significant System Integration effort



# Synergy drive ca 1990

Cardio and Vascular are merged. Digital imaging gets dominant



legend

Geo

Acquisition

Imaging

X-ray generation



matrix organizations within product groups:

mechanical

electrical

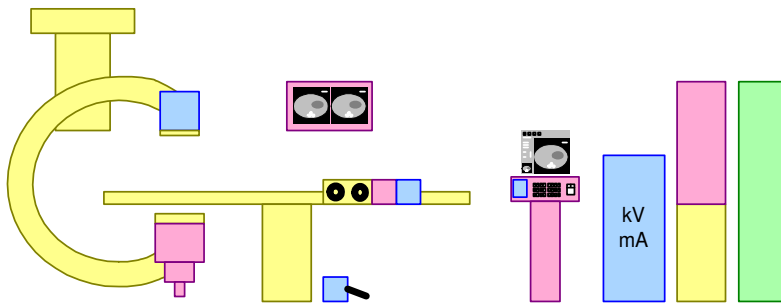
software

application and domain technology know how diluted

software content is significant

test and validation time is significant (> 1 year)

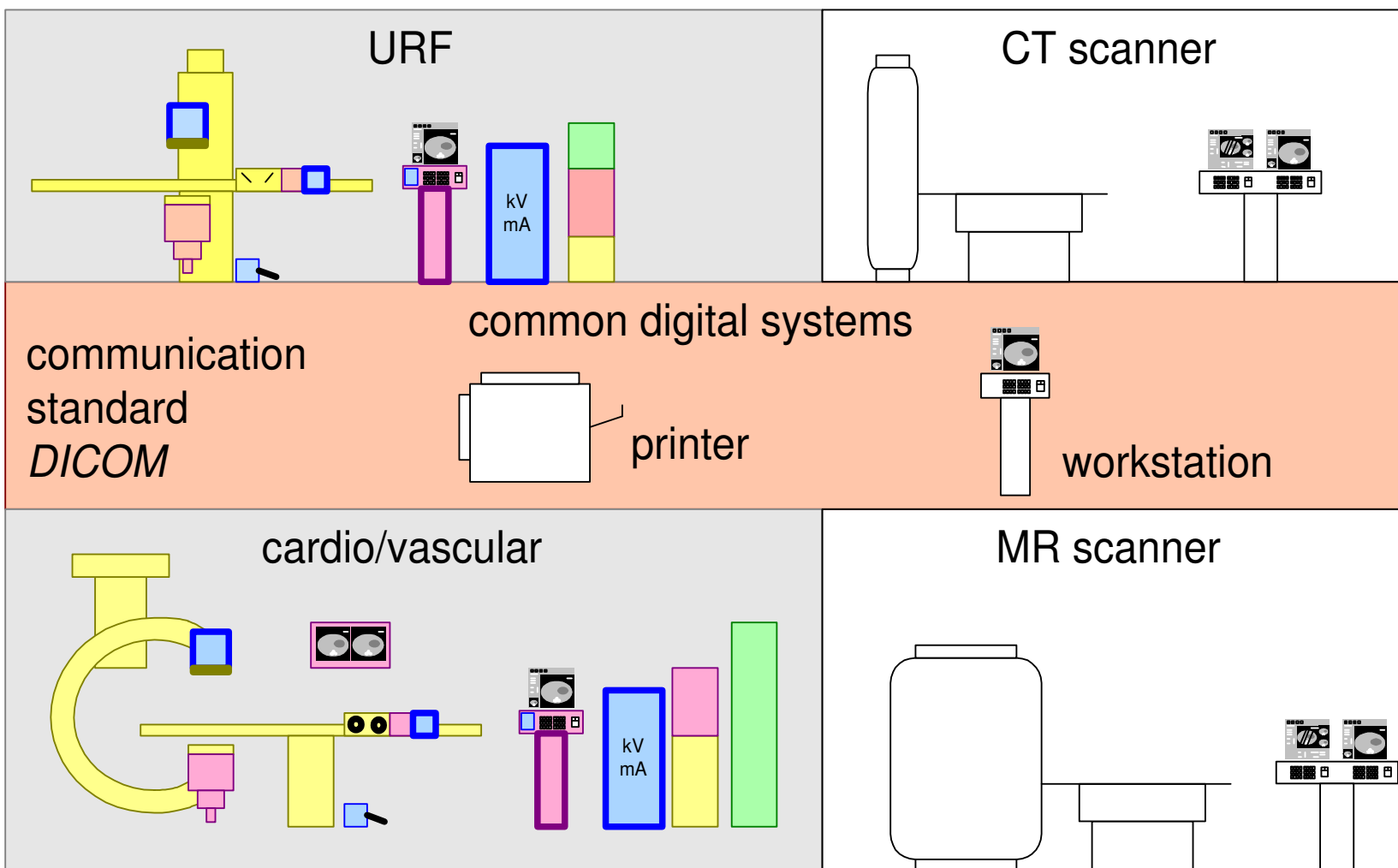
senior designer  $\approx$  system designer



# System: 1995..2000 Synergy Drive

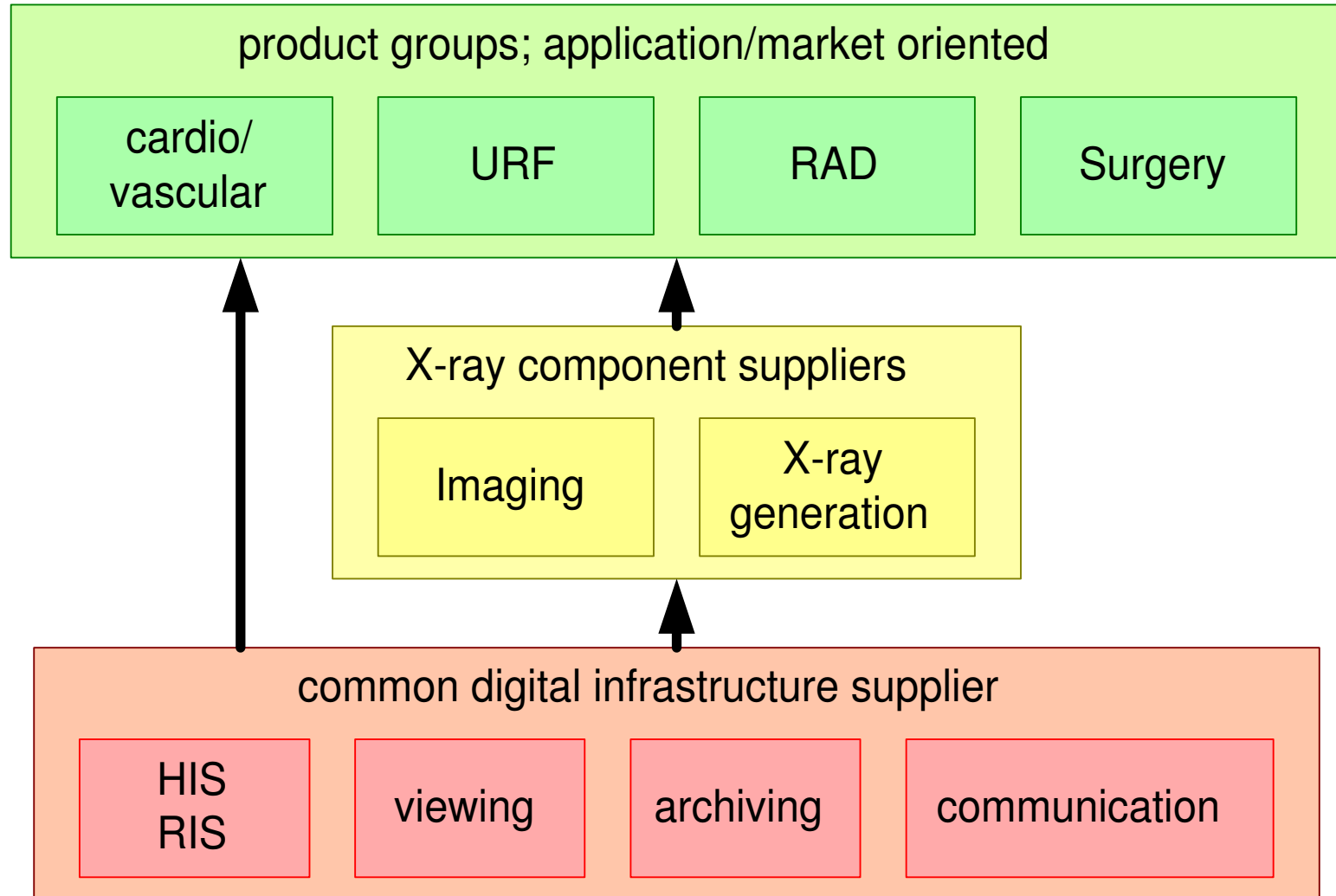
Common X-ray components (imaging, generation, collimators)

Common digital infrastructure (workstations, networks, printers)



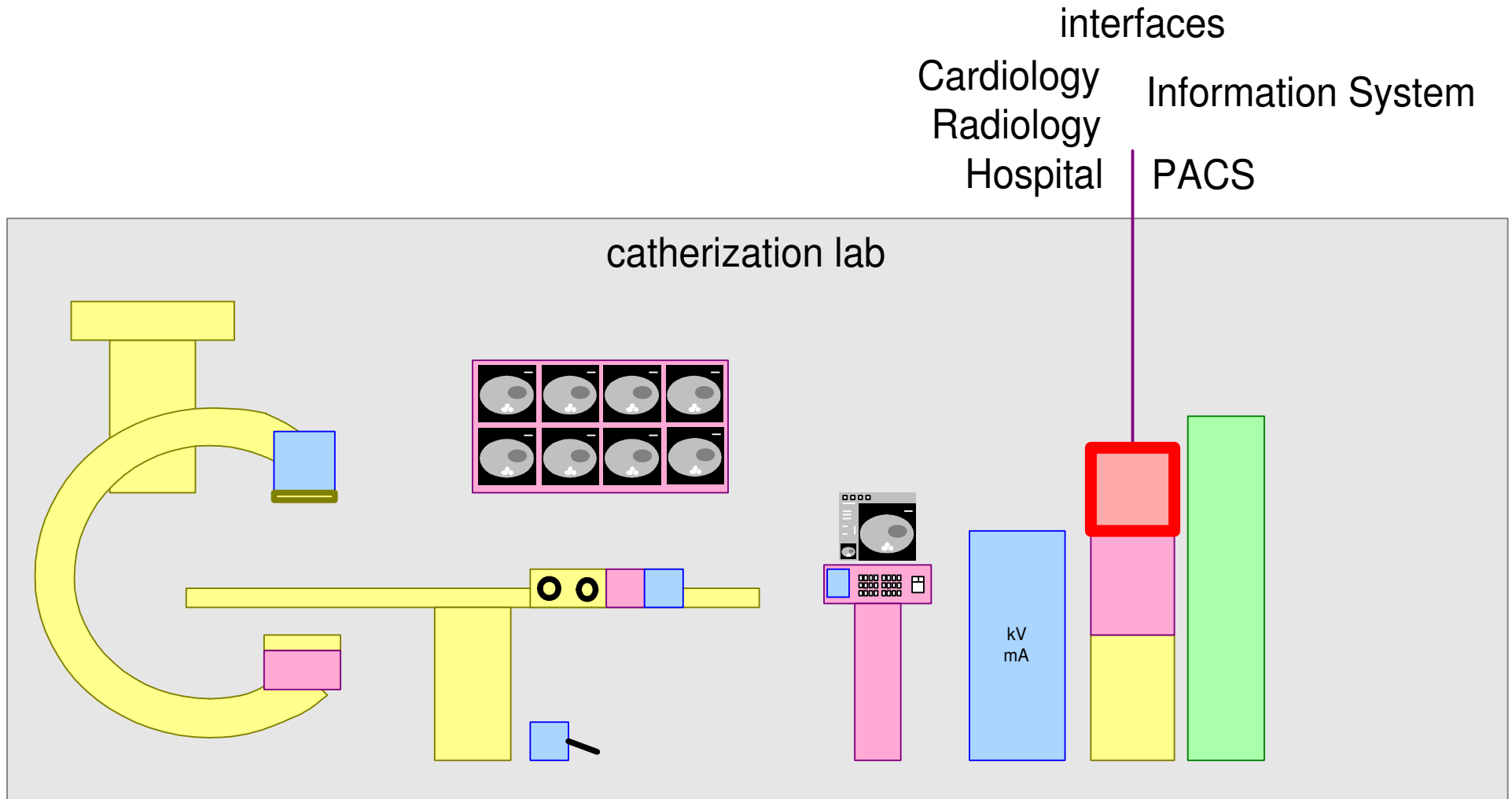
# Organization 1995..2000: Additional Synergy Layer

Common components are organized as separate groups:  
X-ray and PMS-wide



# 2000: Introduction of central System Control

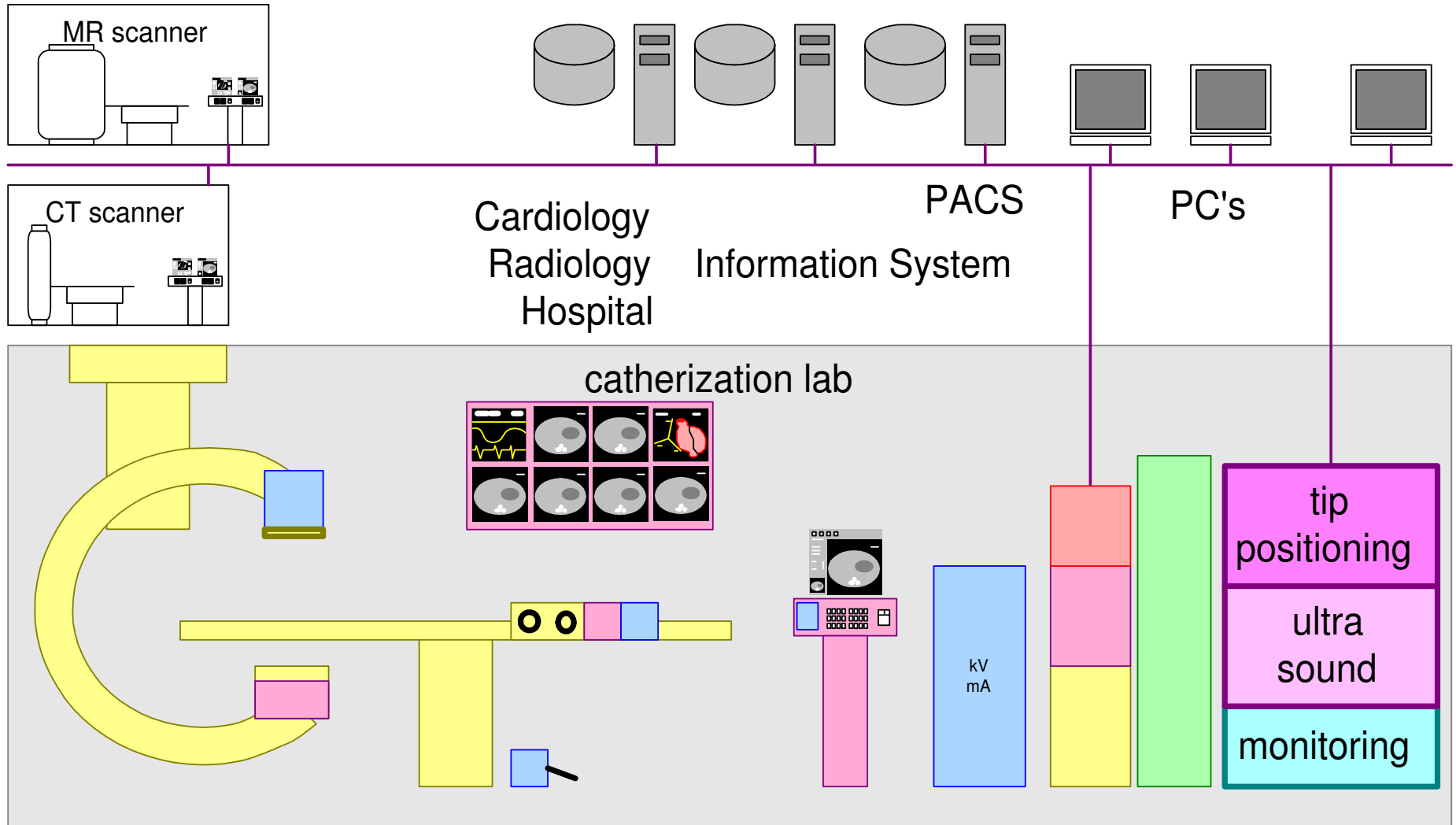
New: system control = industrial PC + Windows XP + **4 Mloc** + 3rd party SW



# System: 2005 System of Systems?

Catherization Laboratory integrates many systems

and is heavily connected to other health care departments and systems

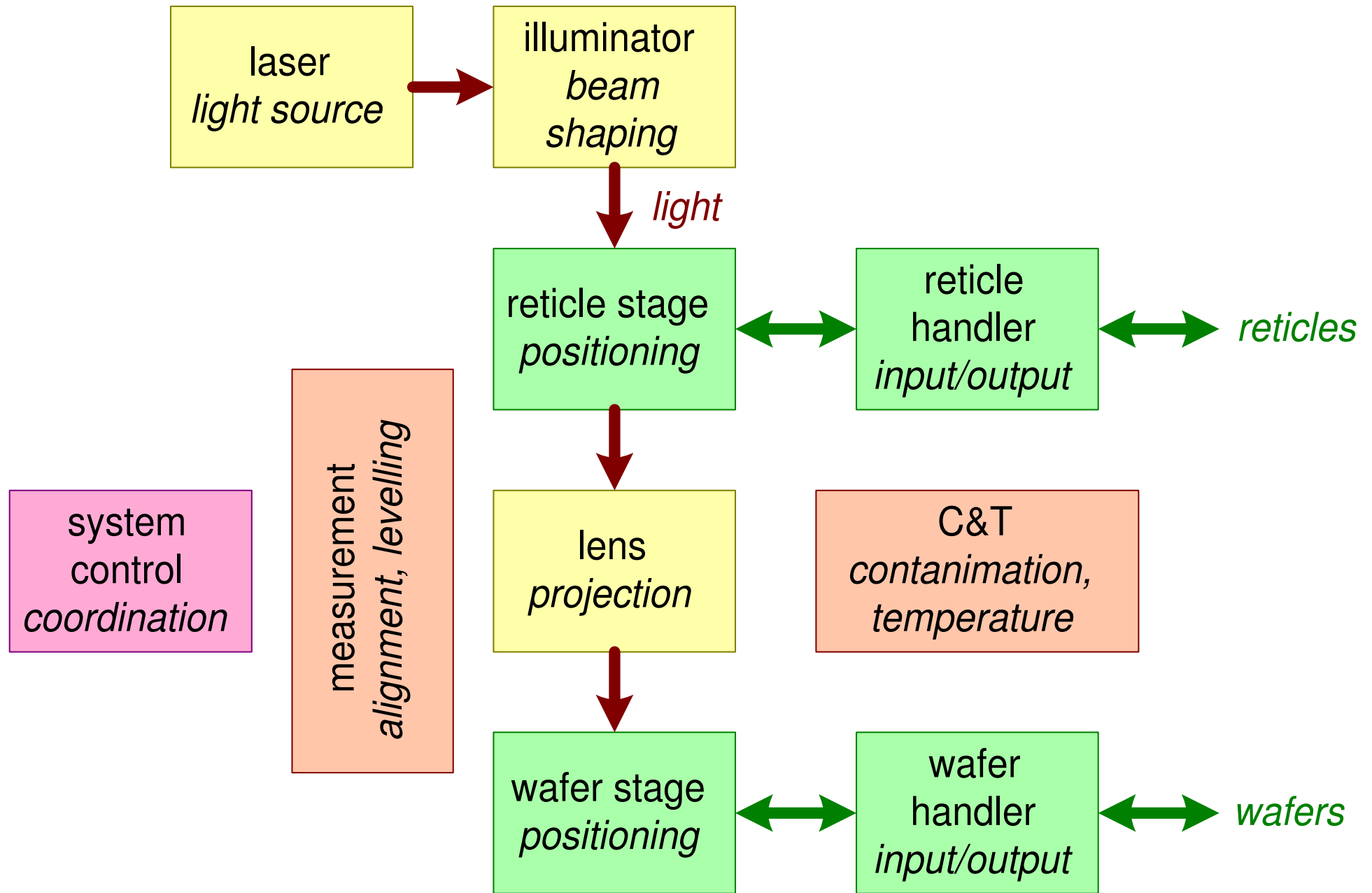




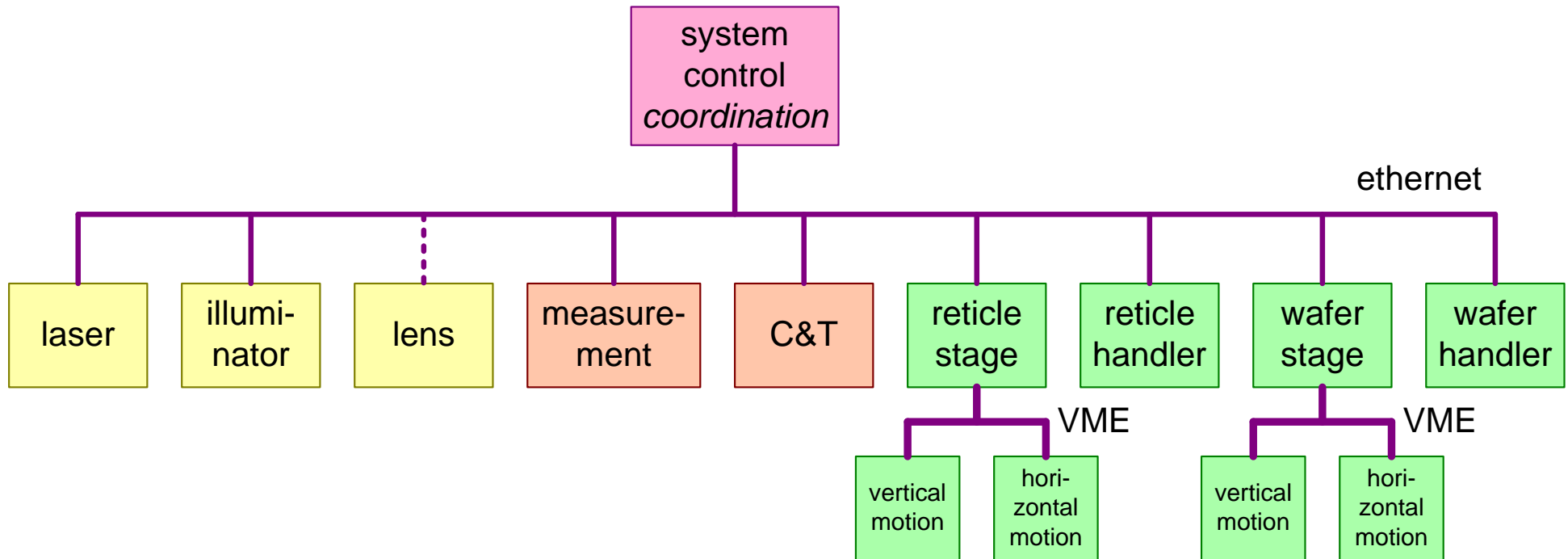
# Characterization per Phase

	<i>electro-mechanical components</i>	<i>autonomous subsystems</i>	<i>synergy</i>	<i>system control</i>	<i>system of systems</i>
system	<i>emerging</i>	<i>R&amp;D integration</i>	<i>R&amp;D integration</i>	<i>hierarchy</i>	<i>emerging</i>
dominant concern	<i>modularity</i>	<i>configuration management</i>	<i>synergy</i>	<i>synergy</i>	<i>market value</i>
staff	<i>all round</i>	<i>all round + gurus</i>	<i>disciplines M, E, I + grey hairs</i>	<i>disciplines M, E, I + System</i>	<i>disciplines M, E, I + System</i>
organization	<i>domain labs</i>	<i>products subsystems</i>	<i>matrix</i>	<i>layered matrix</i>	<i>+ network</i>
size R&D	<i>tens</i>	<i>hundred</i>	<i>several hundred</i>	<i>hundreds</i>	

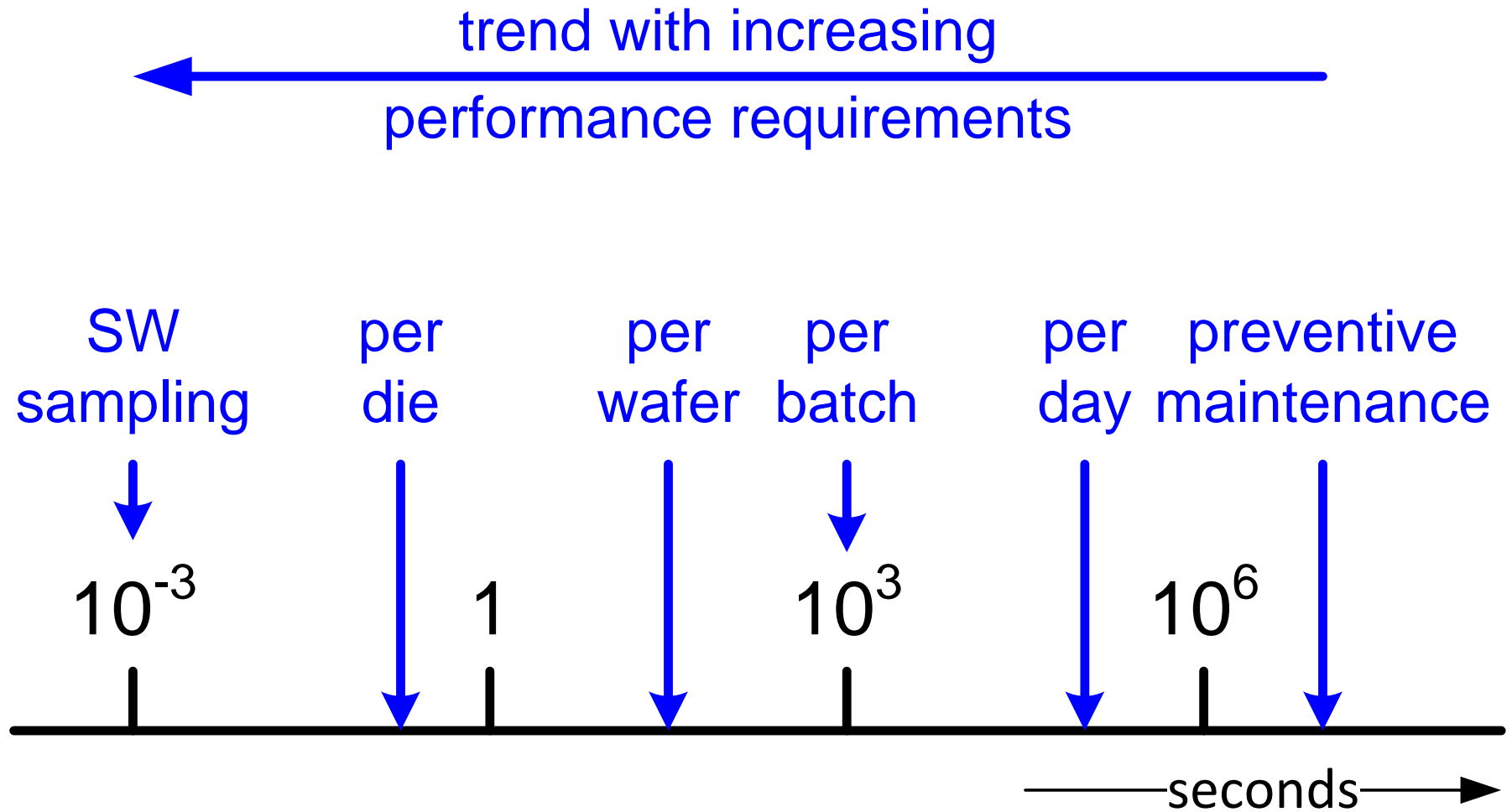
# Block Diagram of a Waferstepper



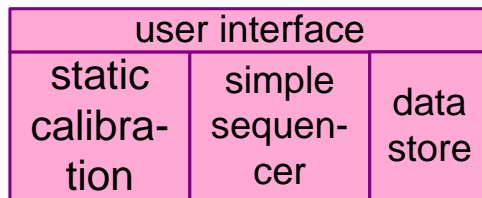
# Control Hierarchy of a Waferstepper



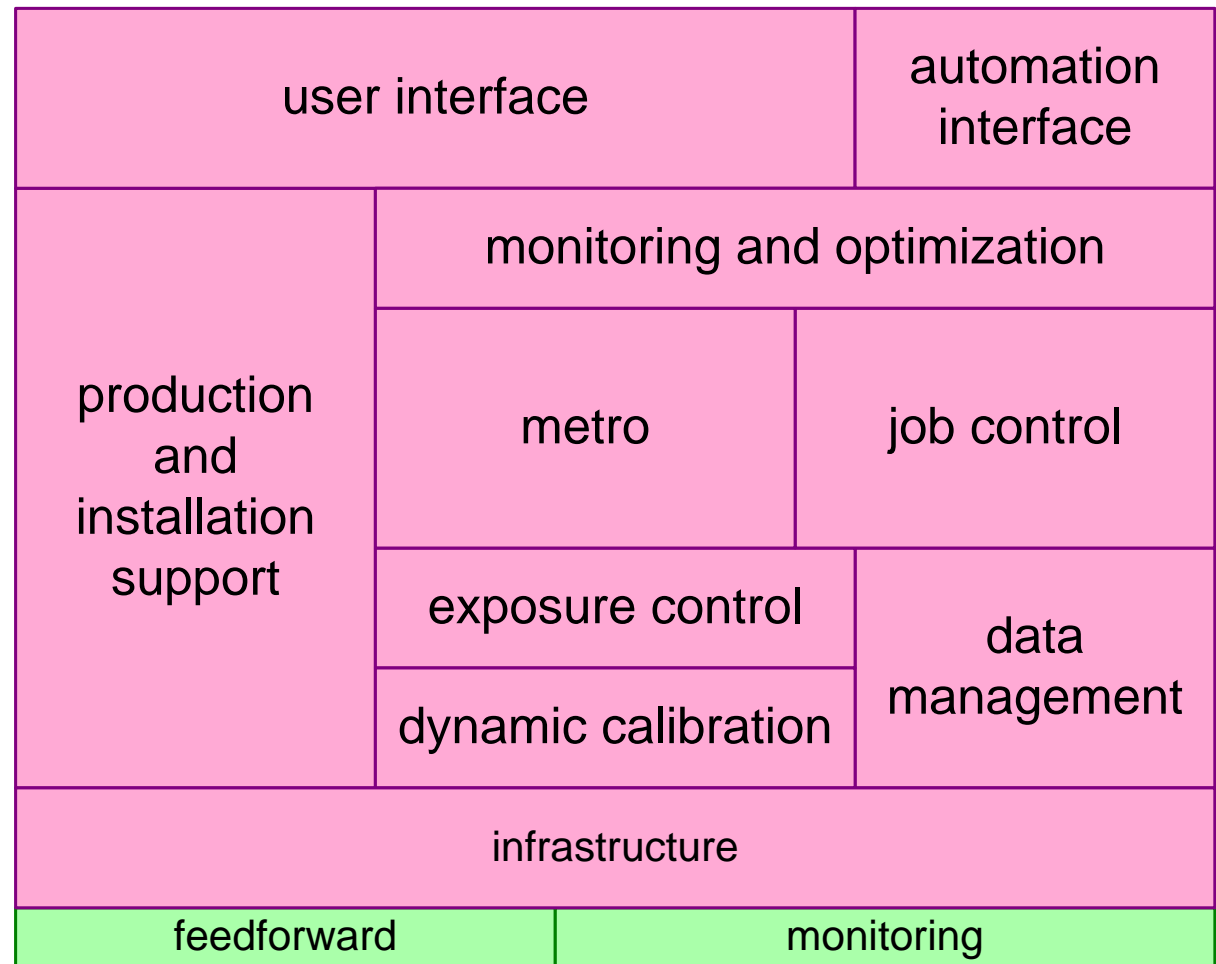
# Frequency of Control Actions



# Evolution of System Control

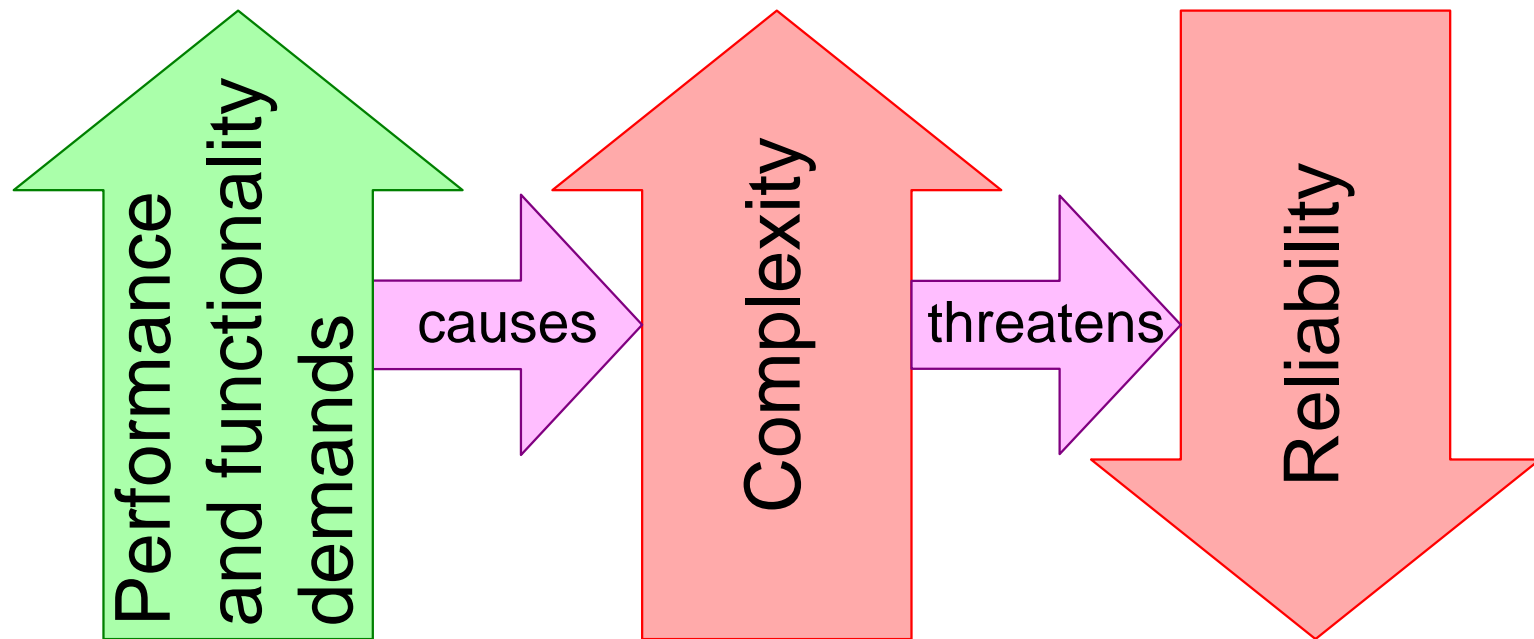


1990  
150 kloc



2000  
2000 kloc

# Consequences of Evolution



loss of overview (150kloc fits in 1 mind, 2Mloc not)  
(more than?) exponential increase of coupling  
1:1 relation HW:SW becomes n:m relation

