

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.

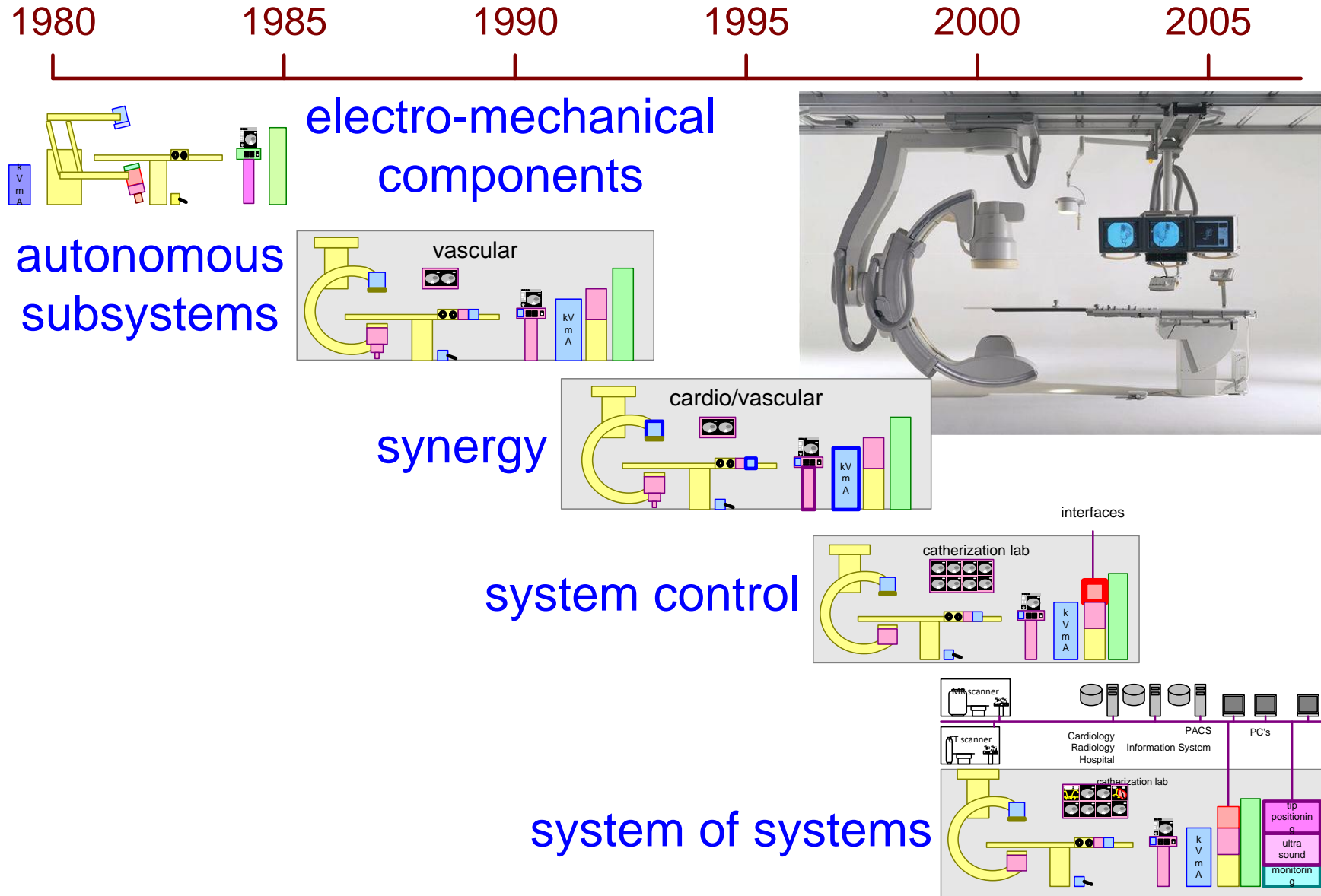
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logo
TBD

Evolution of X-ray Systems



Diagnostic X-ray system 1980

..~1980

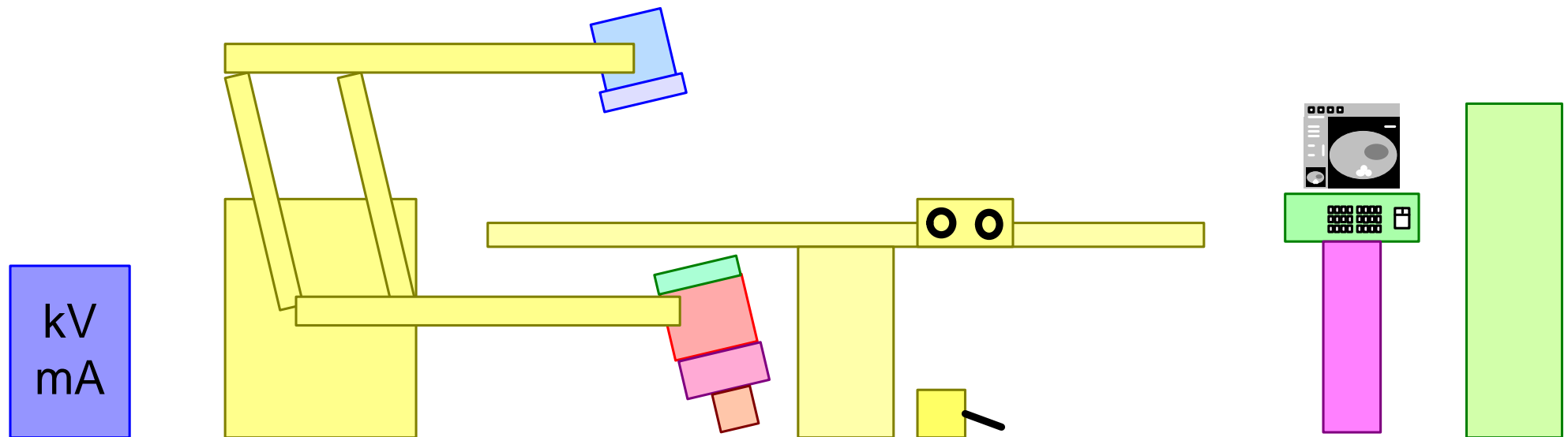
many independent modules most Philips, some 3rd party sales: all configurations are possible

system integration (SI) in factory

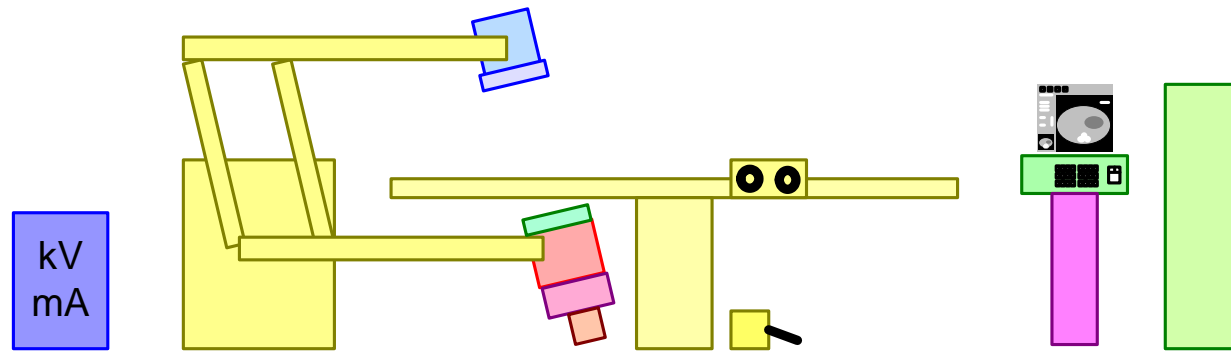
many adaption boxes

SI is mostly electro mechanical

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



Organization in 1980



*innovation
departments*

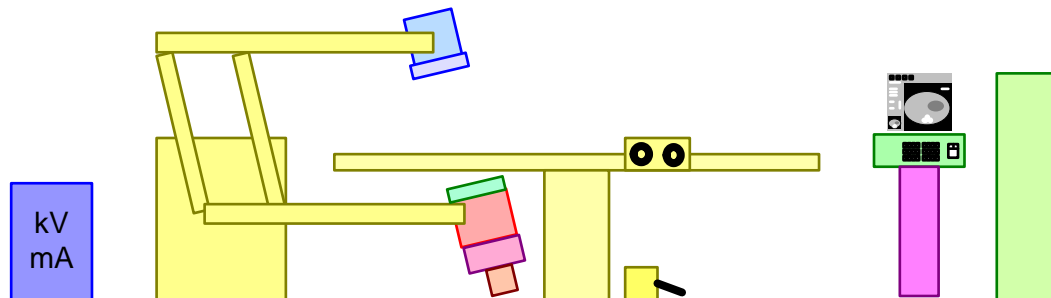
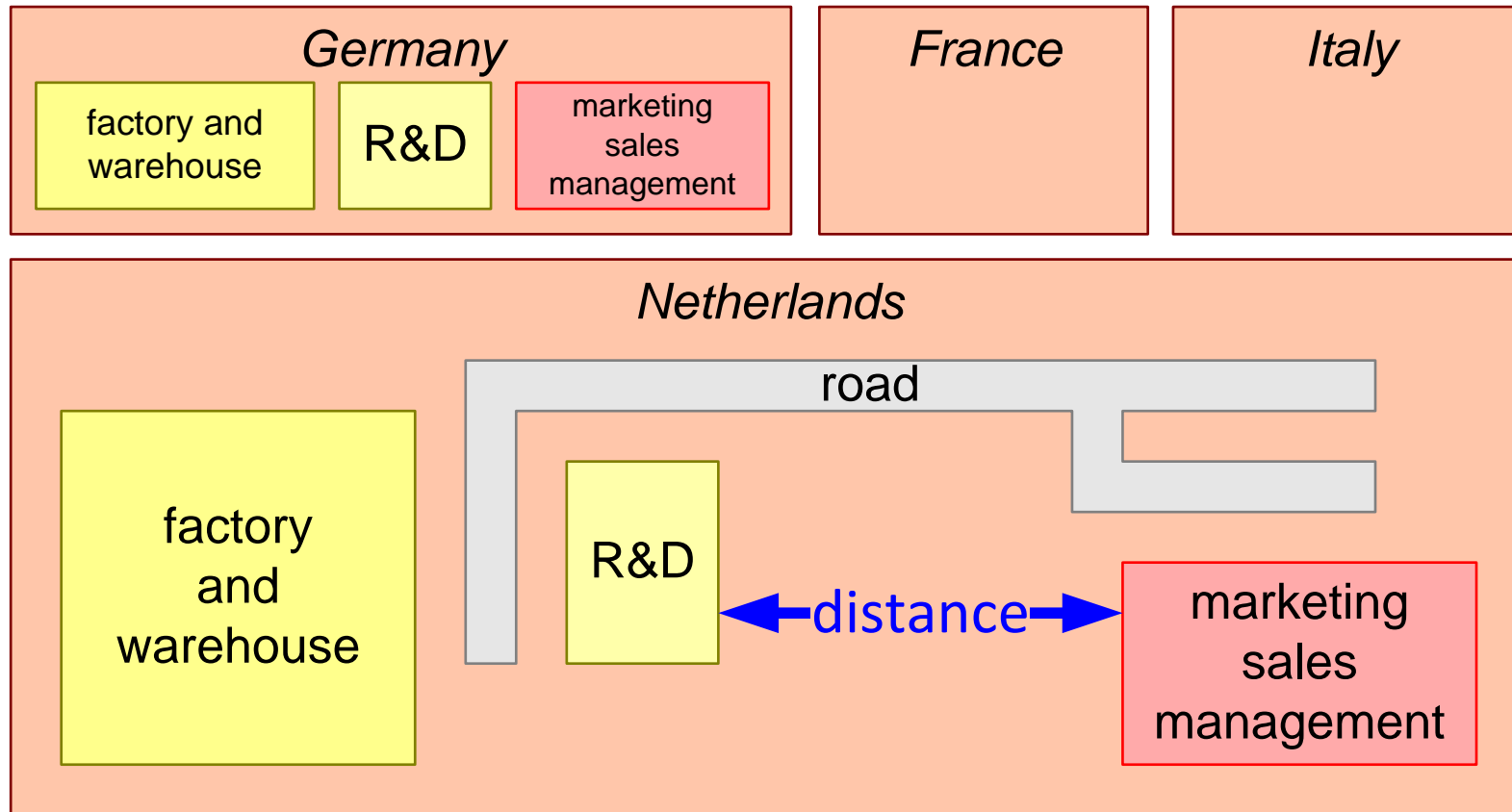
Roentgen
Electronics
Laboratory

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:

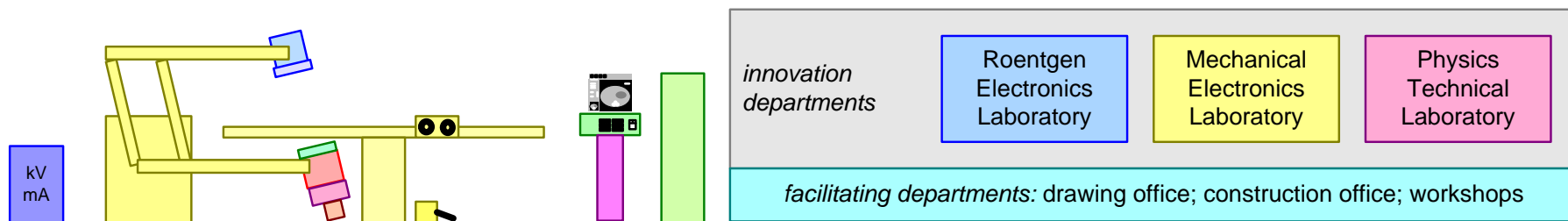
application

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

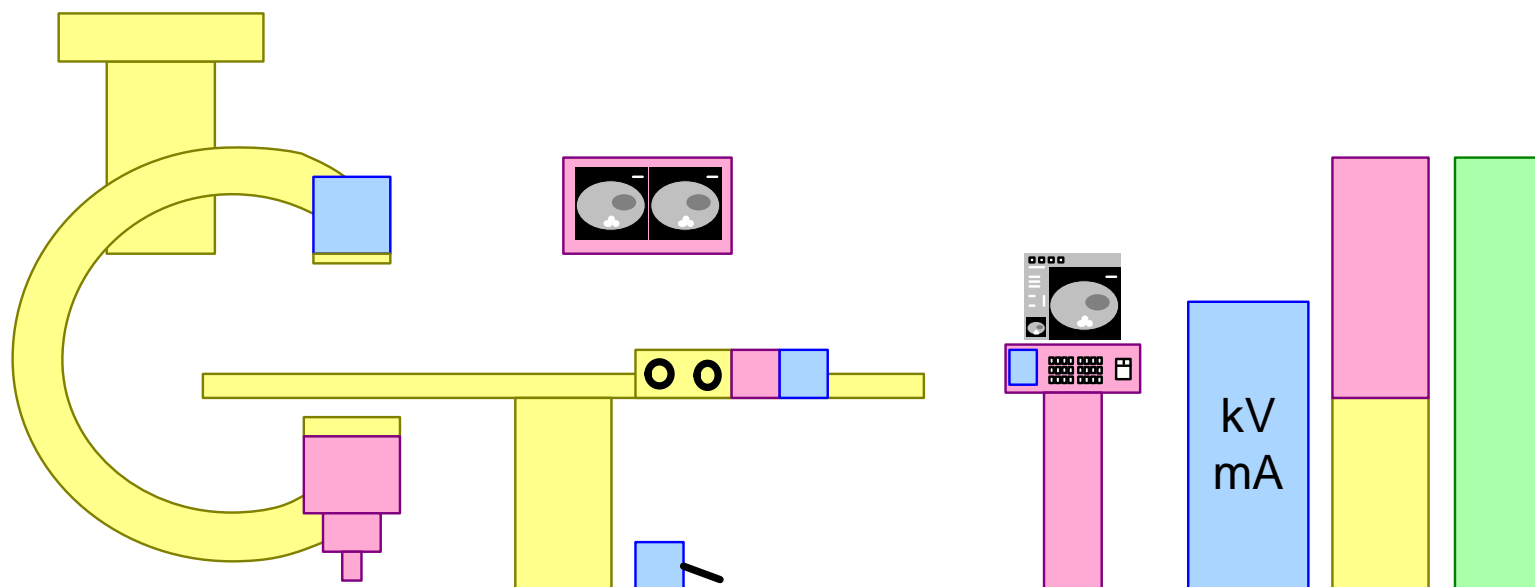
X-ray generator

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

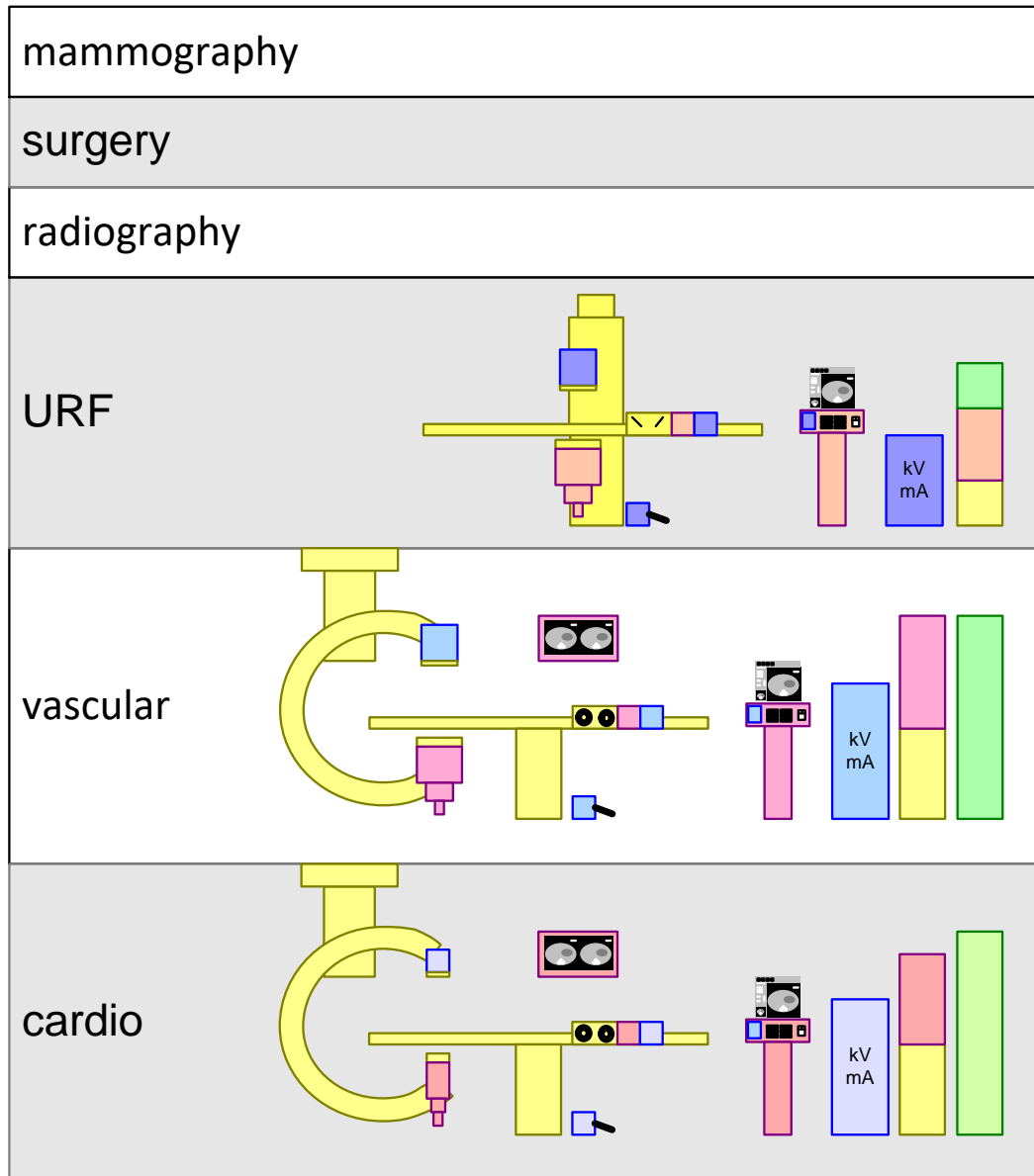
SW in all subsystems

Systems Integration is electro mechanical *and configuration parameters*

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

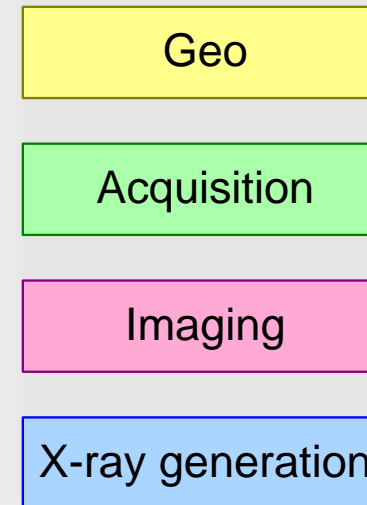


Organization in 1985: Product/Business Oriented



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

legend



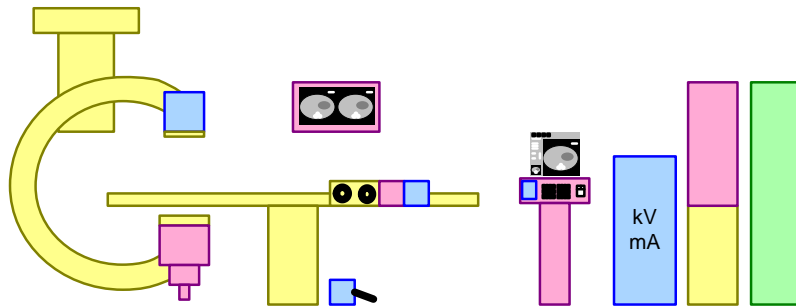
medium sized teams

strong subsystem focus

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

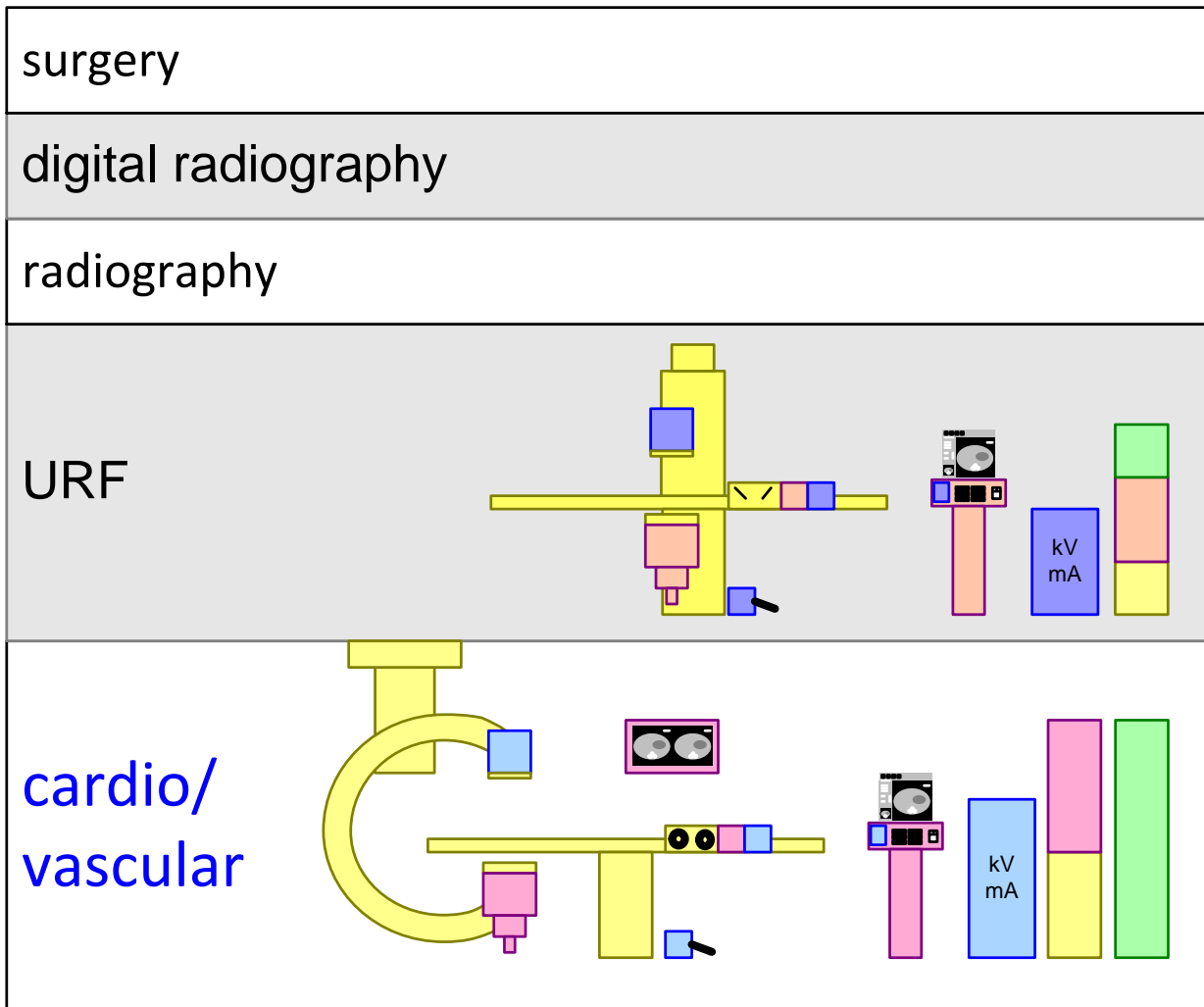
project leader is also system designer

significant System Integration effort



Synergy drive ca 1990

Cardio and Vascular are merged. Digital imaging gets dominant



legend

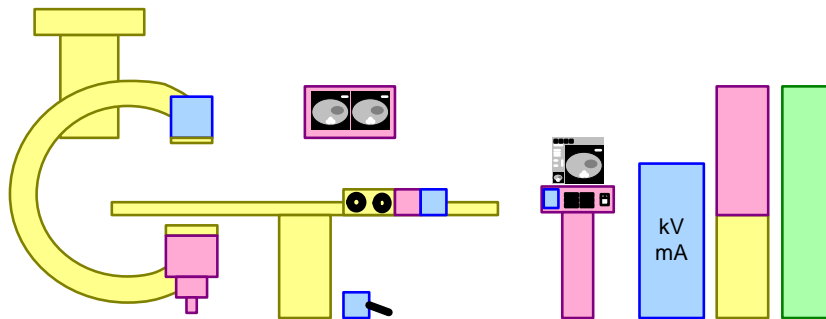
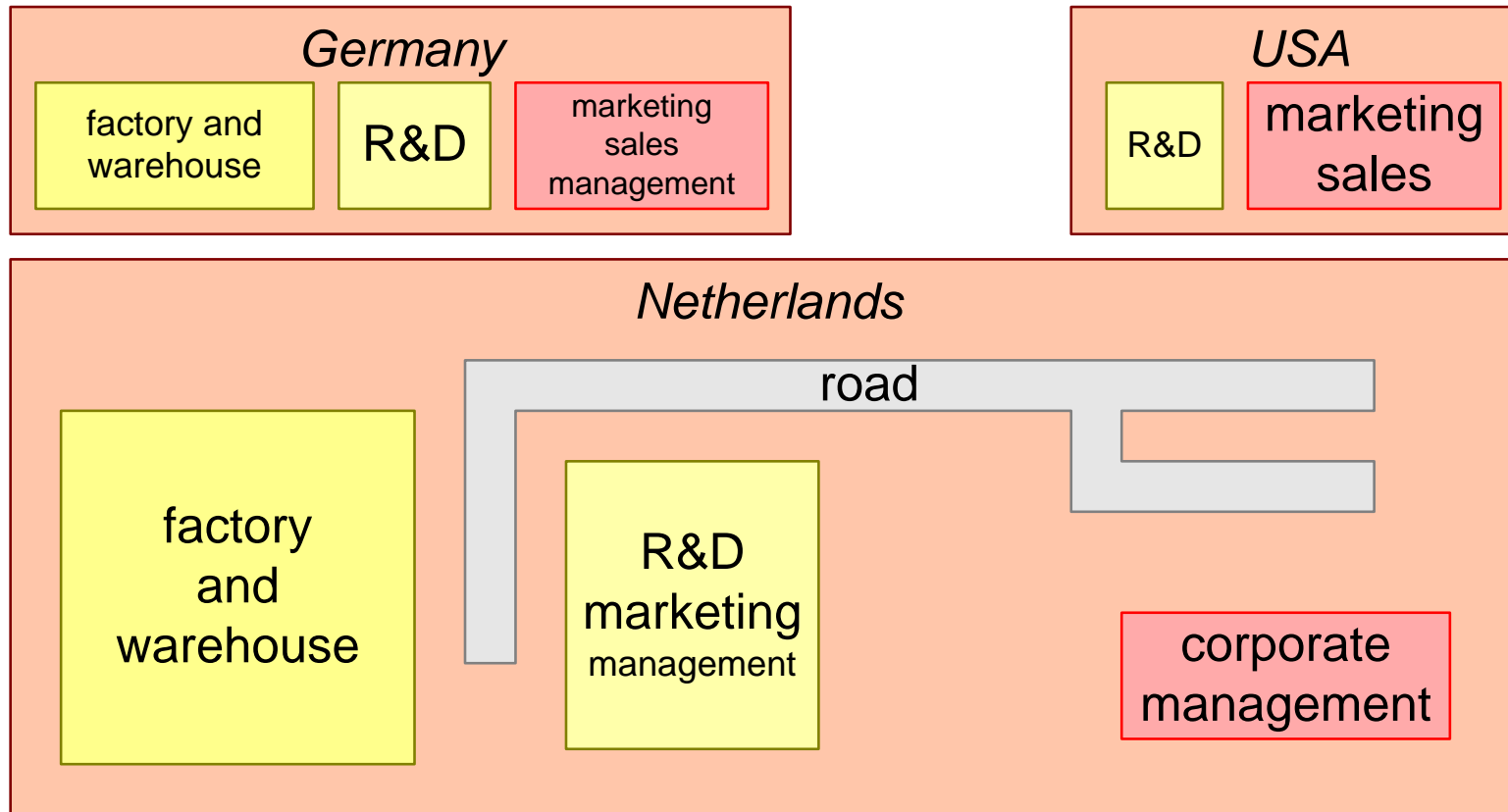
Geo

Acquisition

Imaging

X-ray generation

Geographical locations in 1990



matrix organizations within product groups:

mechanical

electrical

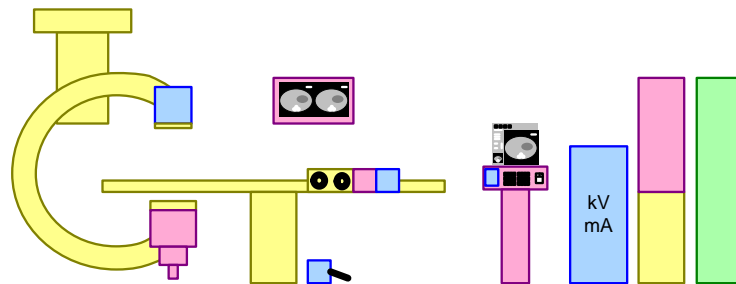
software

application and domain technology know how diluted

software content is significant

test and validation time is significant (> 1 year)

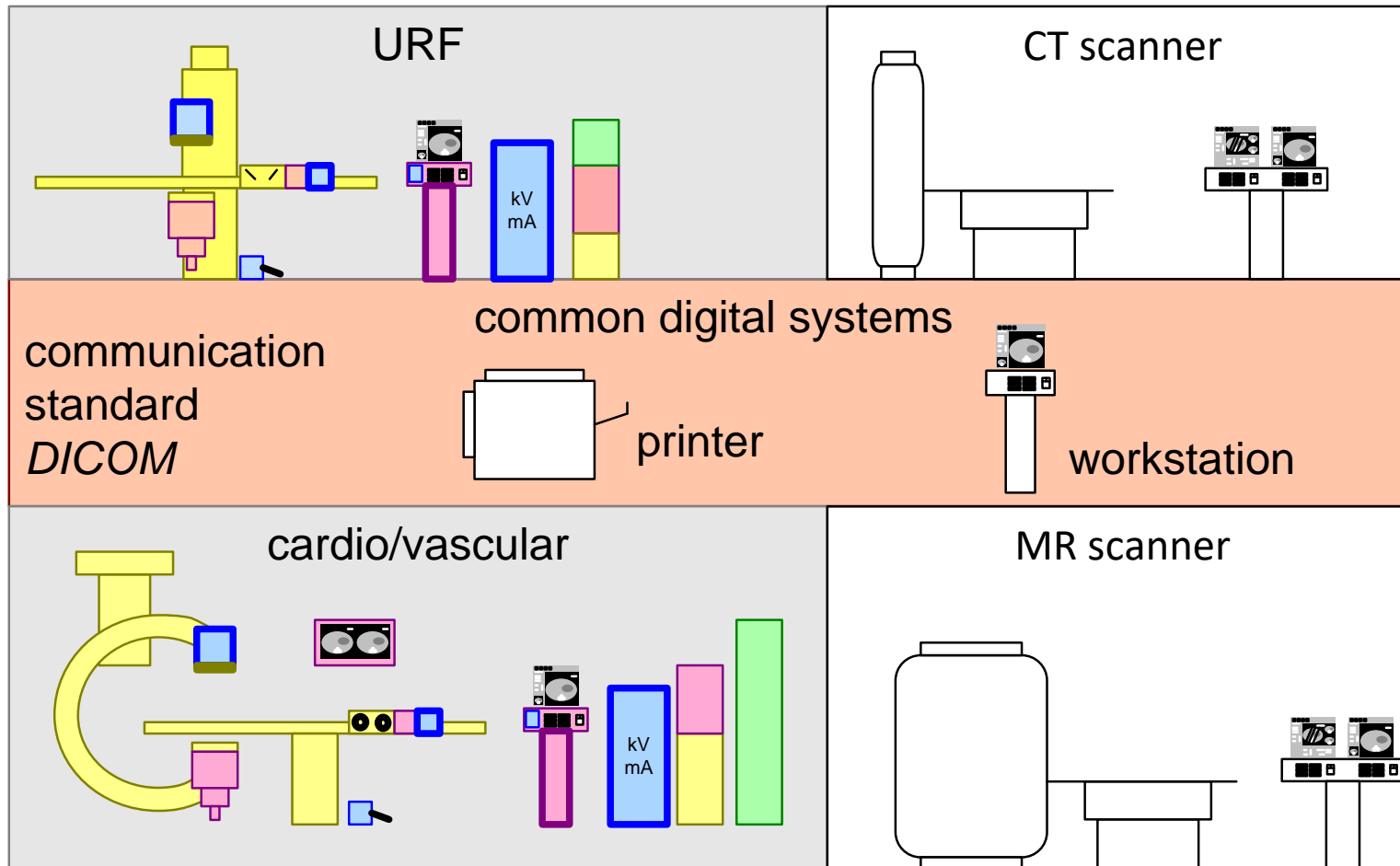
senior designer \approx system designer



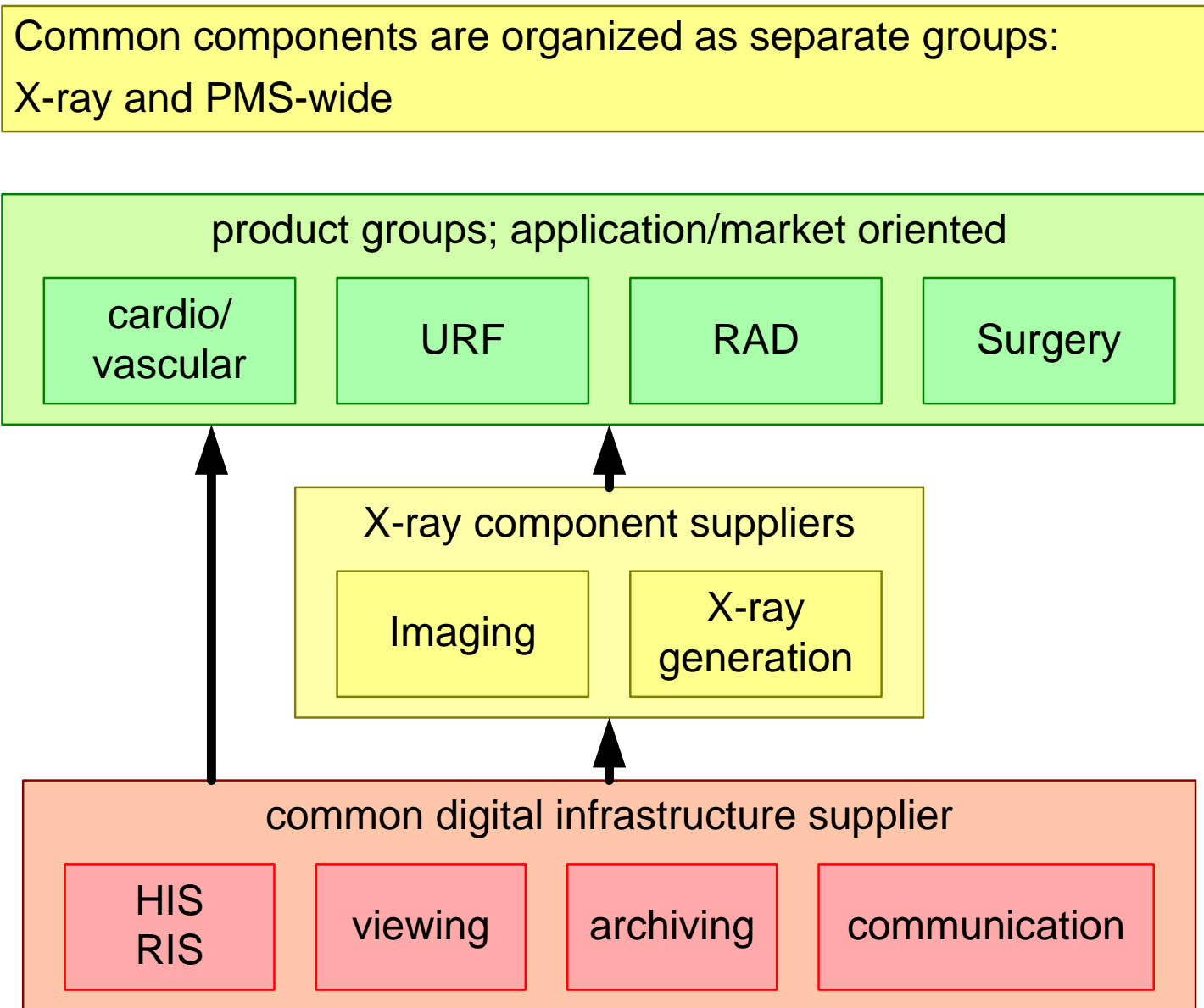
System: 1995..2000 Synergy Drive

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

Common digital infrastructure (workstations, networks, printers)

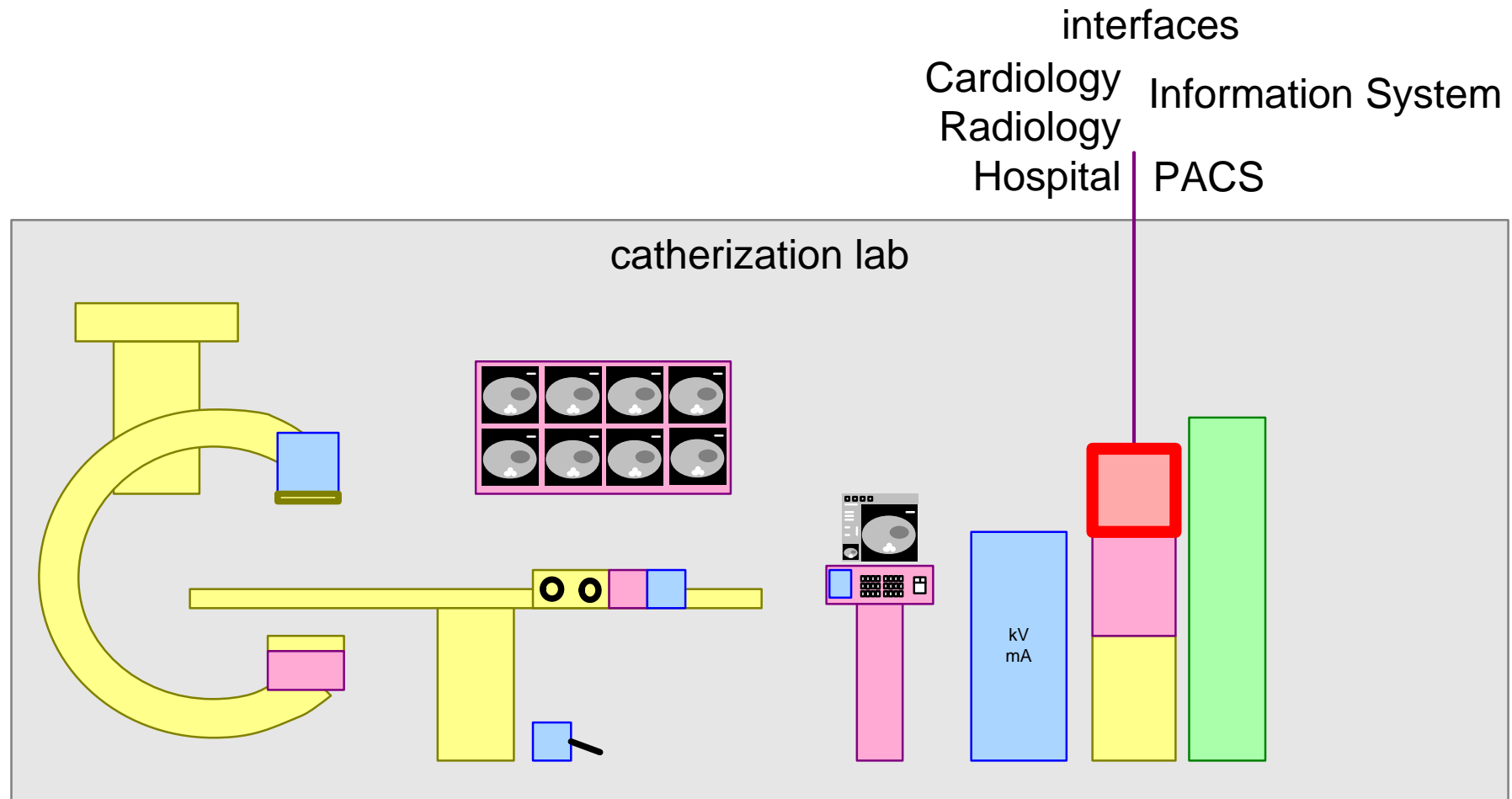


Organization 1995..2000: Additional Synergy Layer



2000: Introduction of central System Control

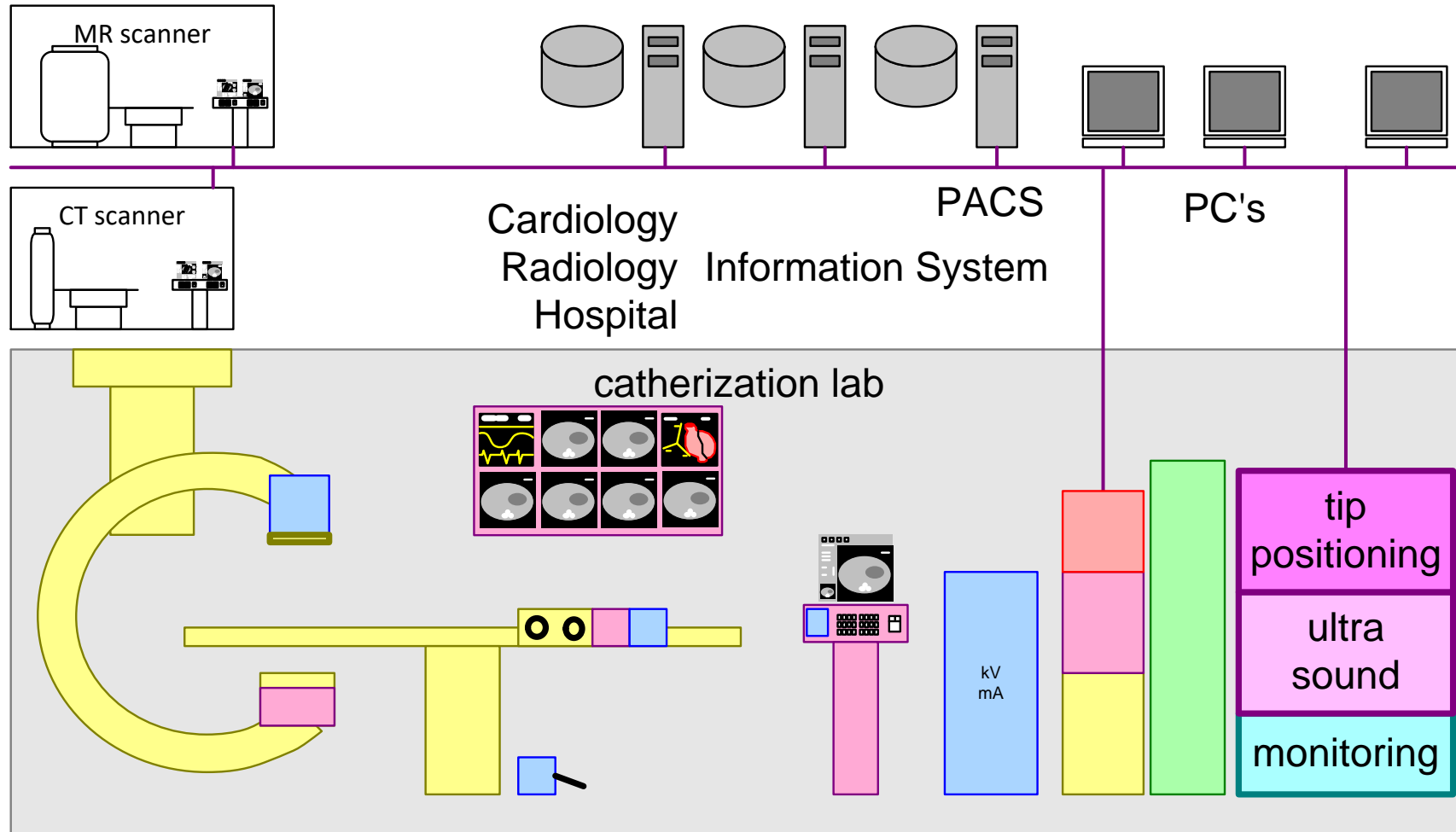
New: system control = industrial PC + Windows XP + **4 Mloc** + 3rd party SW



System: 2005 System of Systems?

Catherization Laboratory integrates many systems

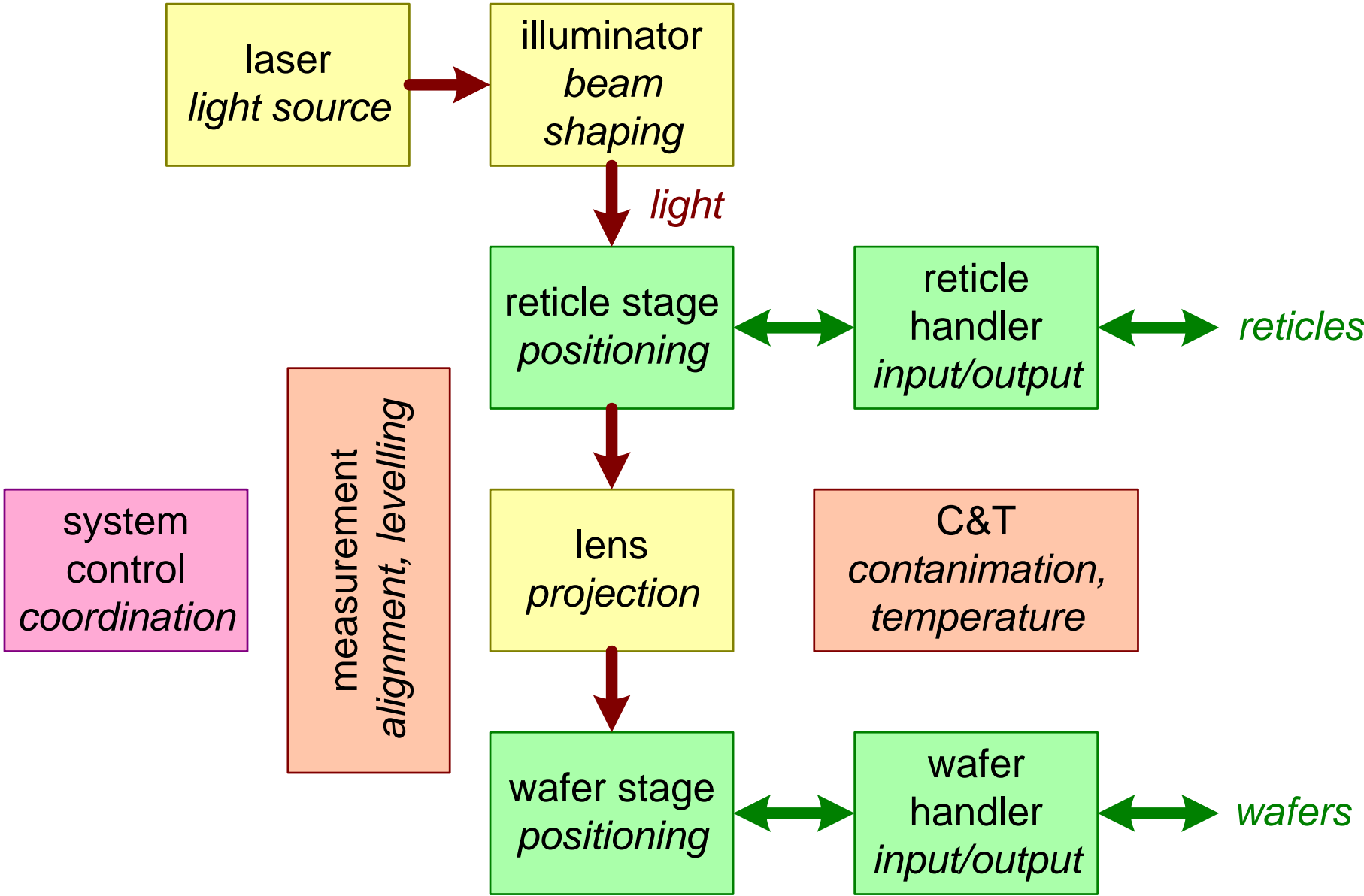
and is heavily connected to other health care departments and systems



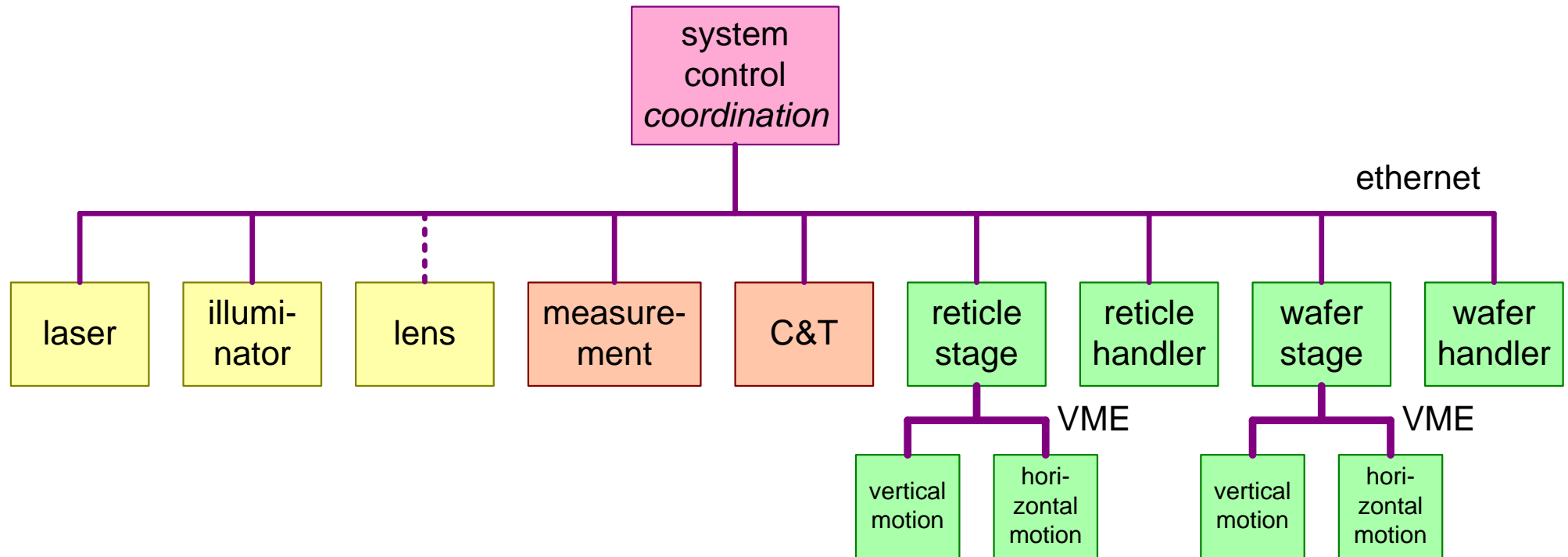
Characterization per Phase

	electro-mechanical components	autonomous subsystems	synergy	system control	system of systems
system	<i>emerging</i>	<i>R&D integration</i>	<i>R&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>	

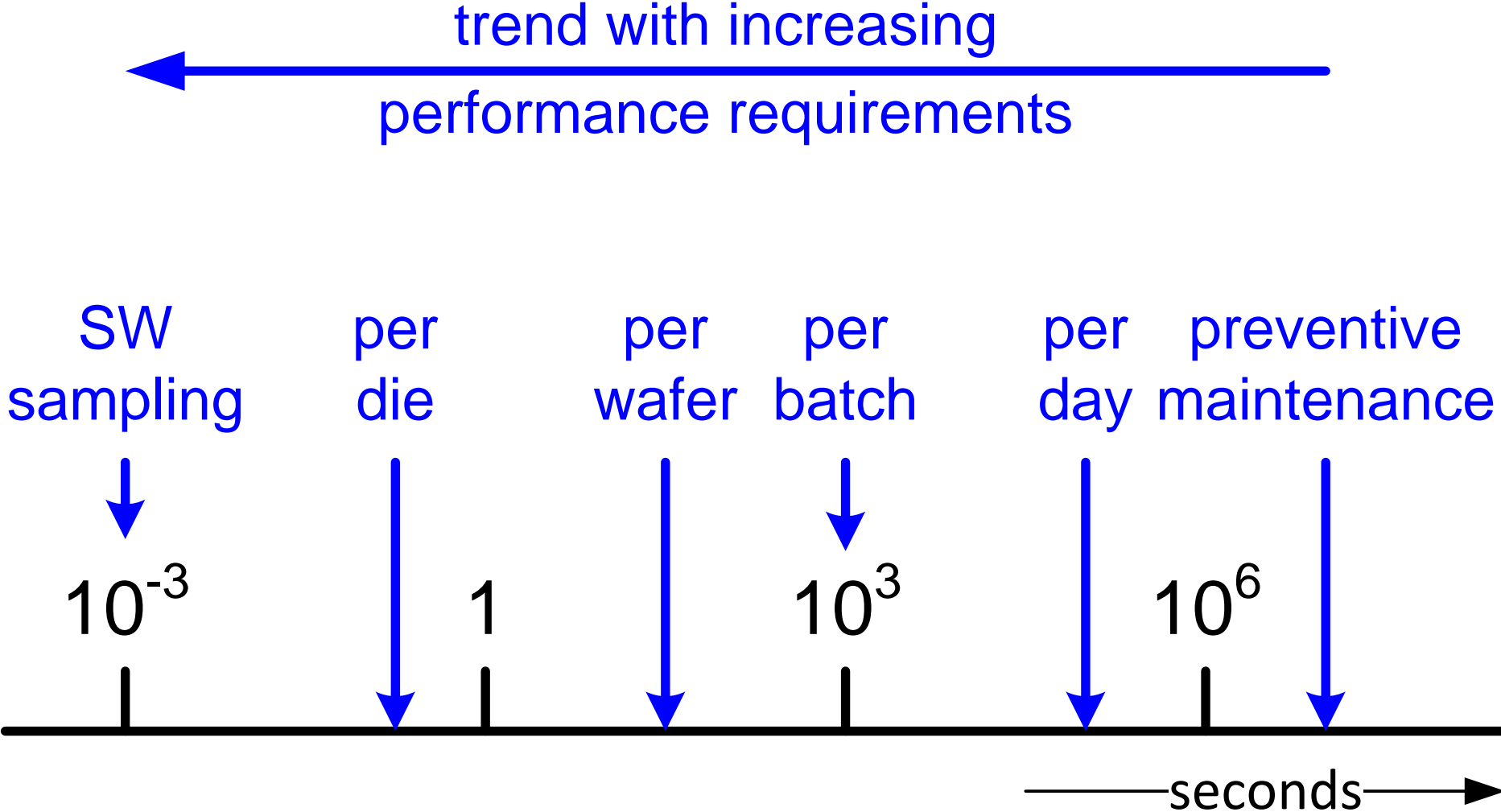
Block Diagram of a Waferstepper



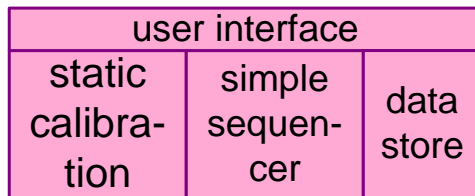
Control Hierarchy of a Waferstepper



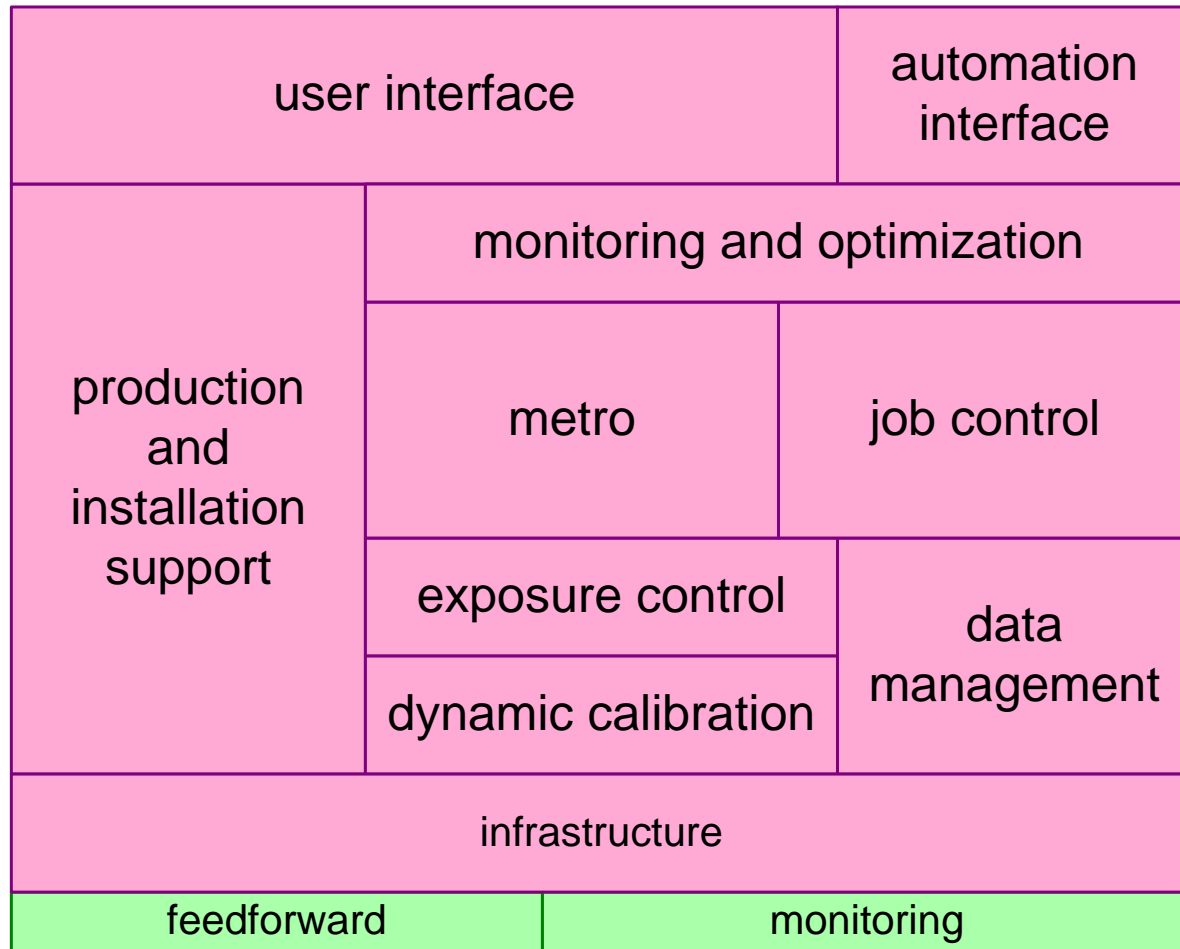
Frequency of Control Actions



Evolution of System Control

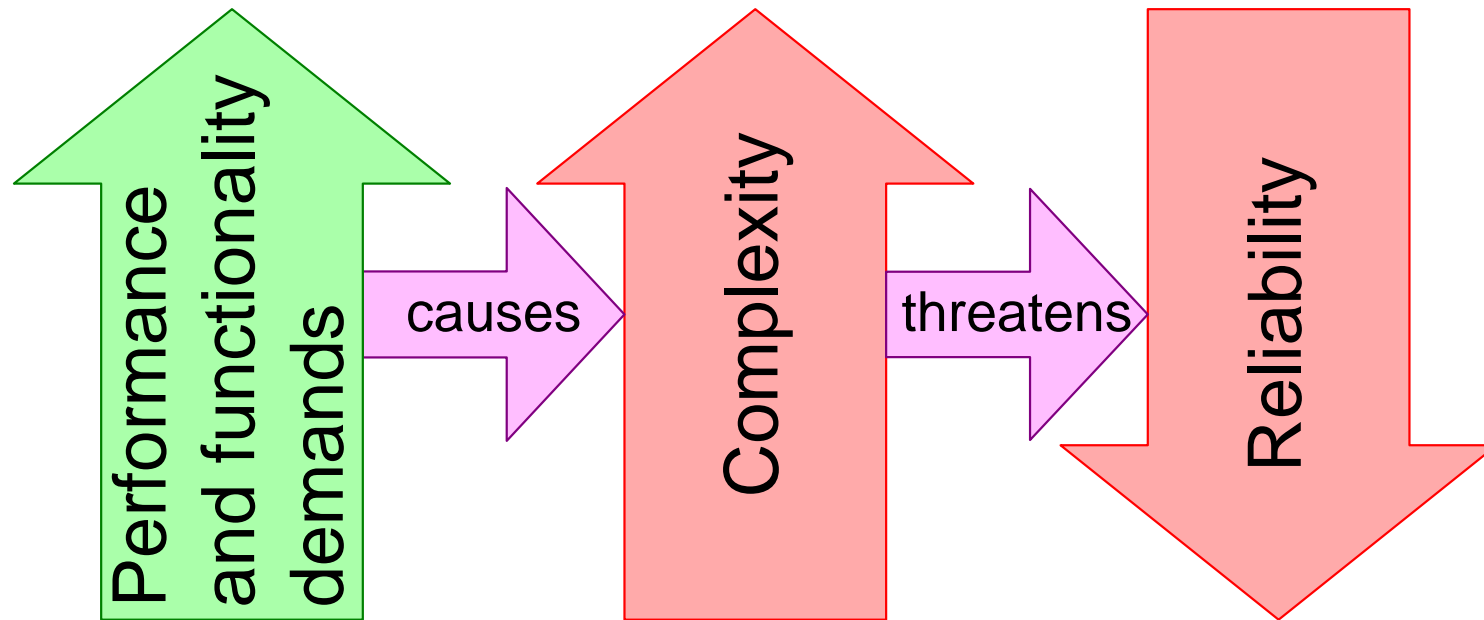


1990
150 kloc



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

