

# 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.

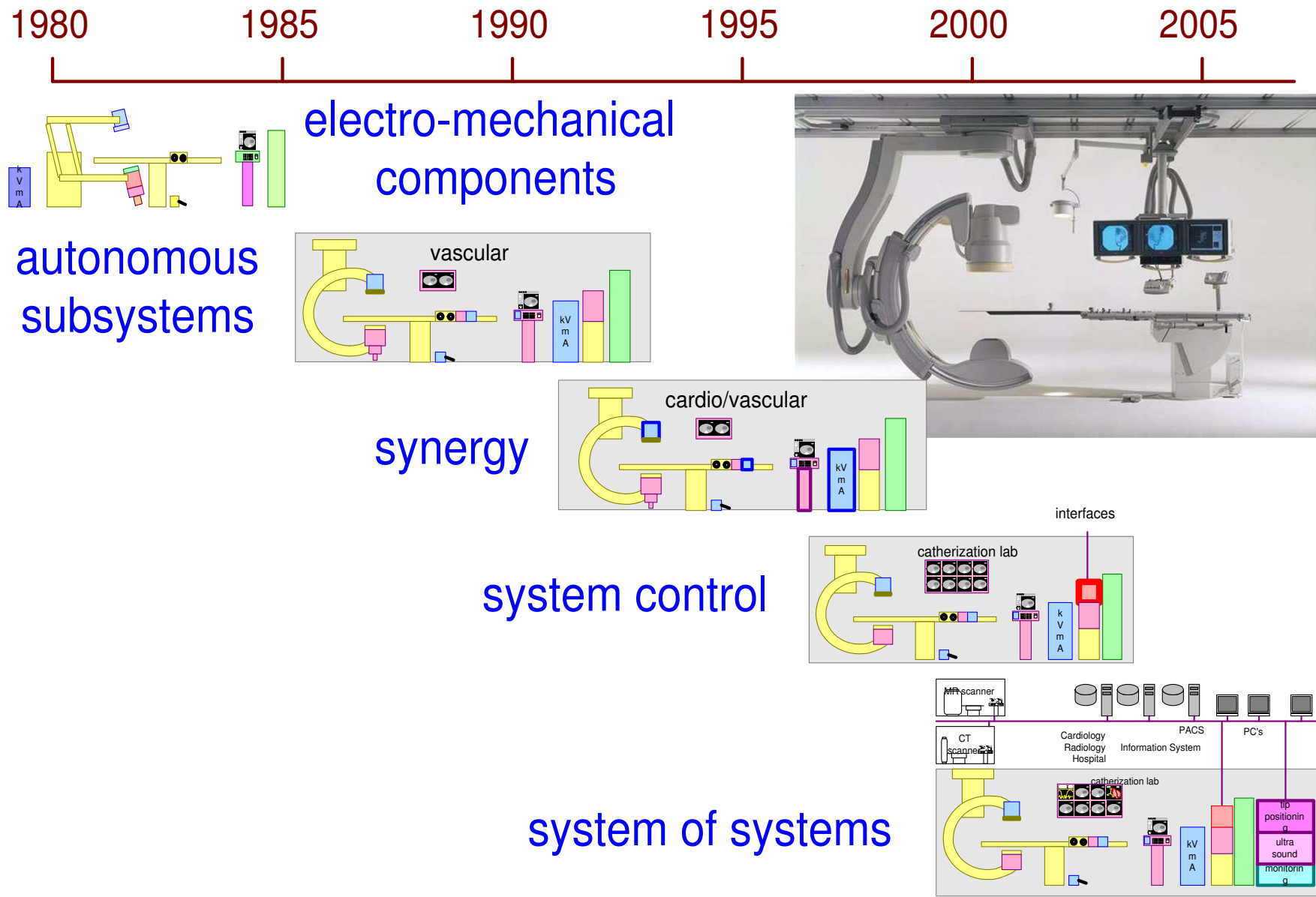
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logo  
TBD

# Evolution of X-ray Systems



# Diagnostic X-ray system 1980

..~1980

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

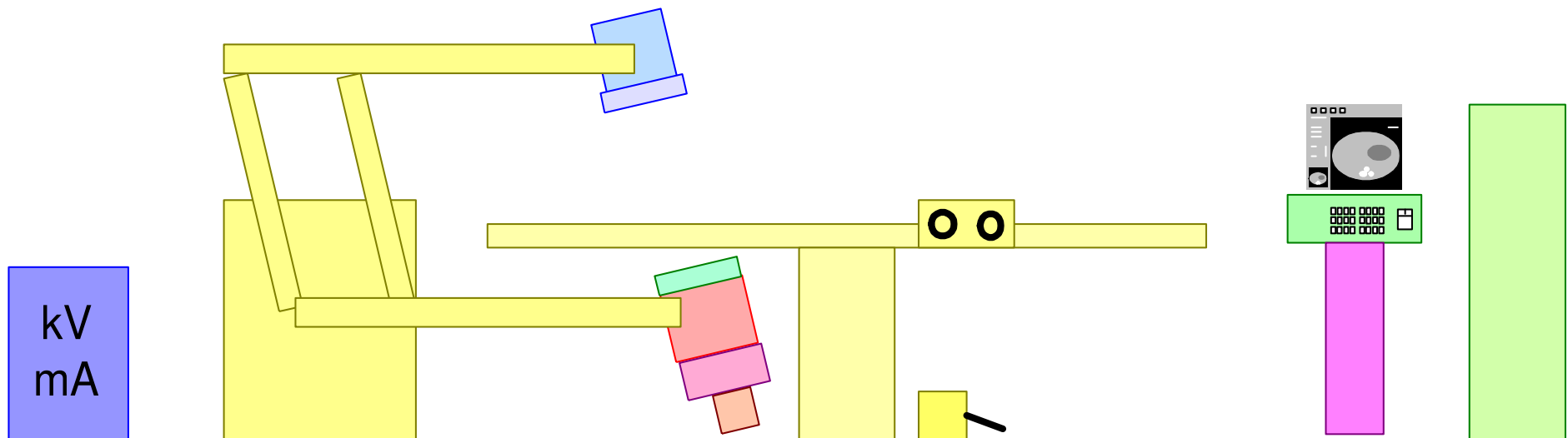
sales: all configurations are possible

system integration (SI) in factory

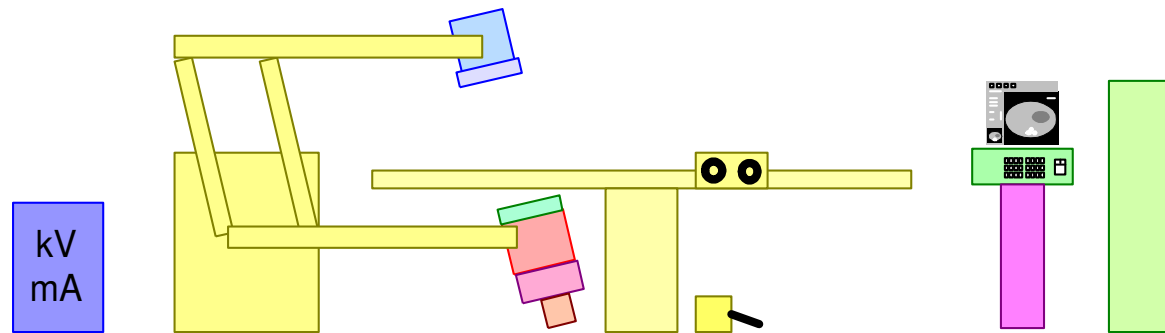
many adaption boxes

SI is mostly electro mechanical

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



# Organization in 1980



*innovation  
departments*

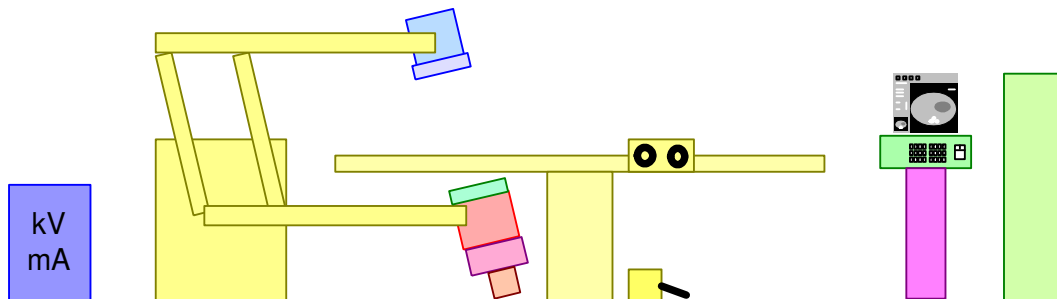
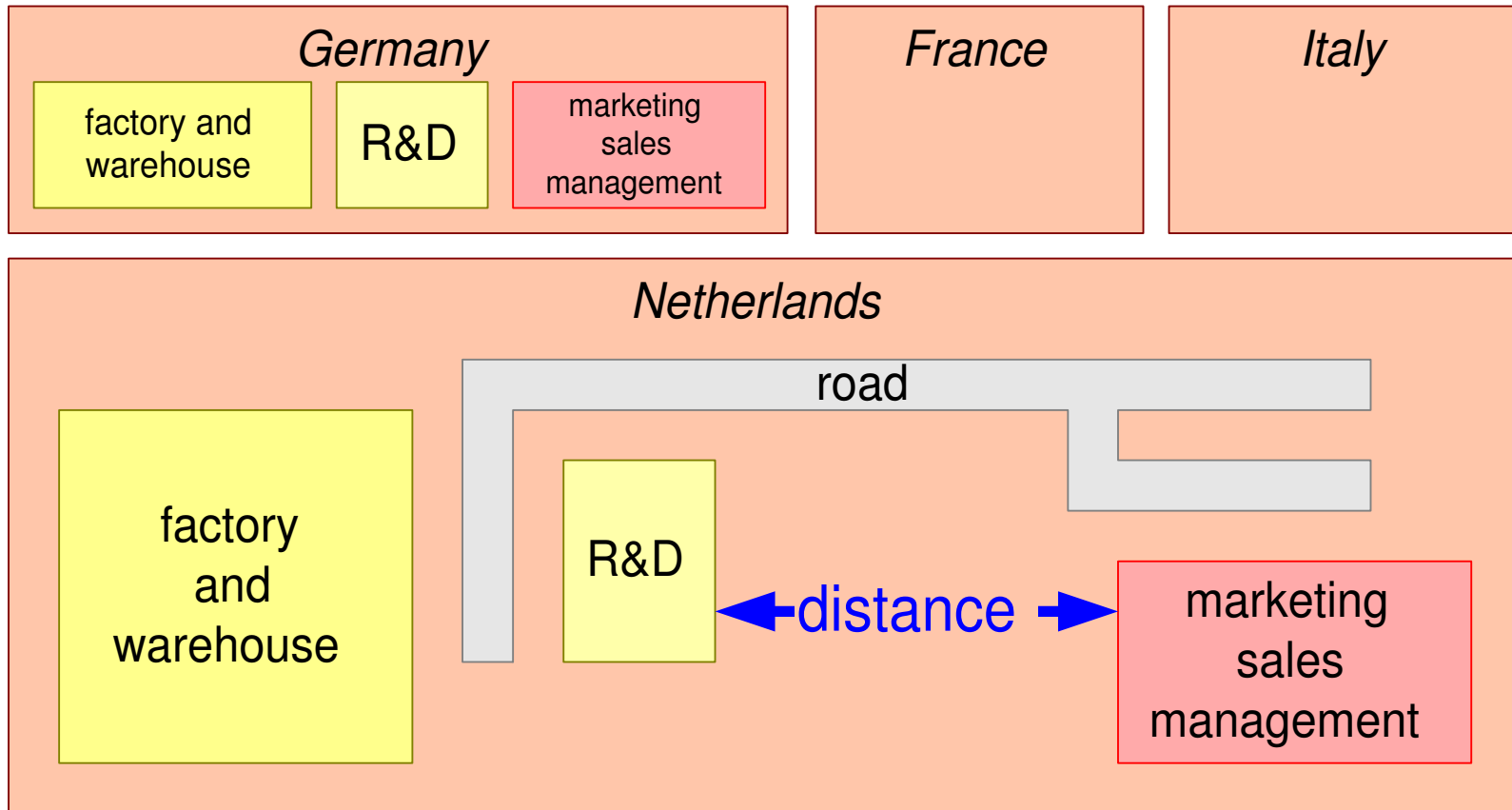
Roentgen  
Electronics  
Laboratory

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:

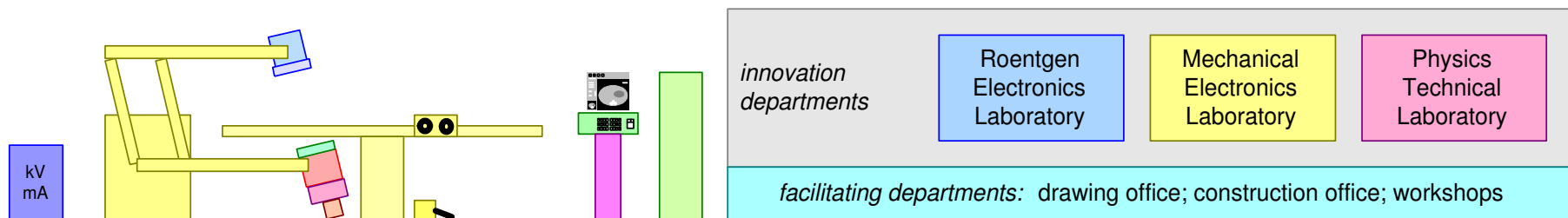
application

senior designer

cardiologist (outside Philips)

application and domain technology implicit in most staff

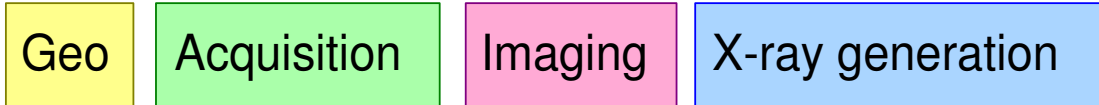
staffing mostly domain technology driven



# Systems 1985..1995

..~1985

autonomous subsystems:



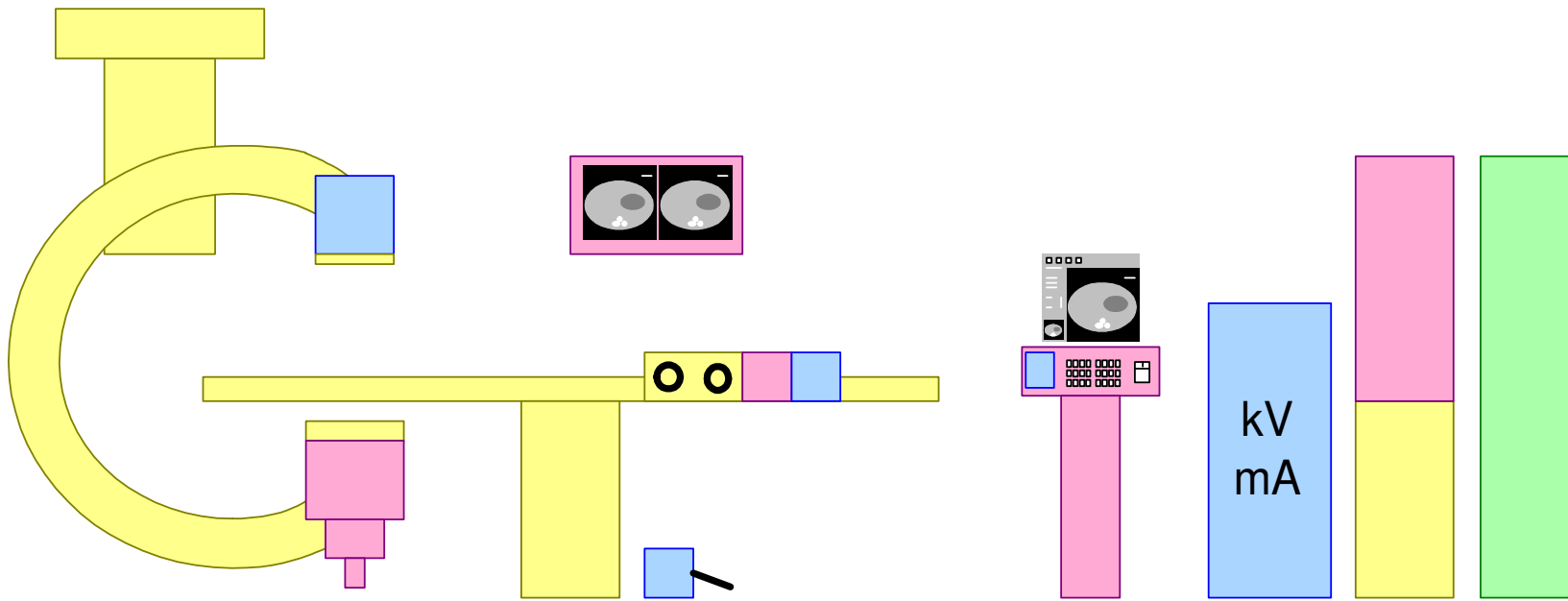
sales: preferred configurations; arbitrary configurations are more expensive

system integration (SI) in R&D

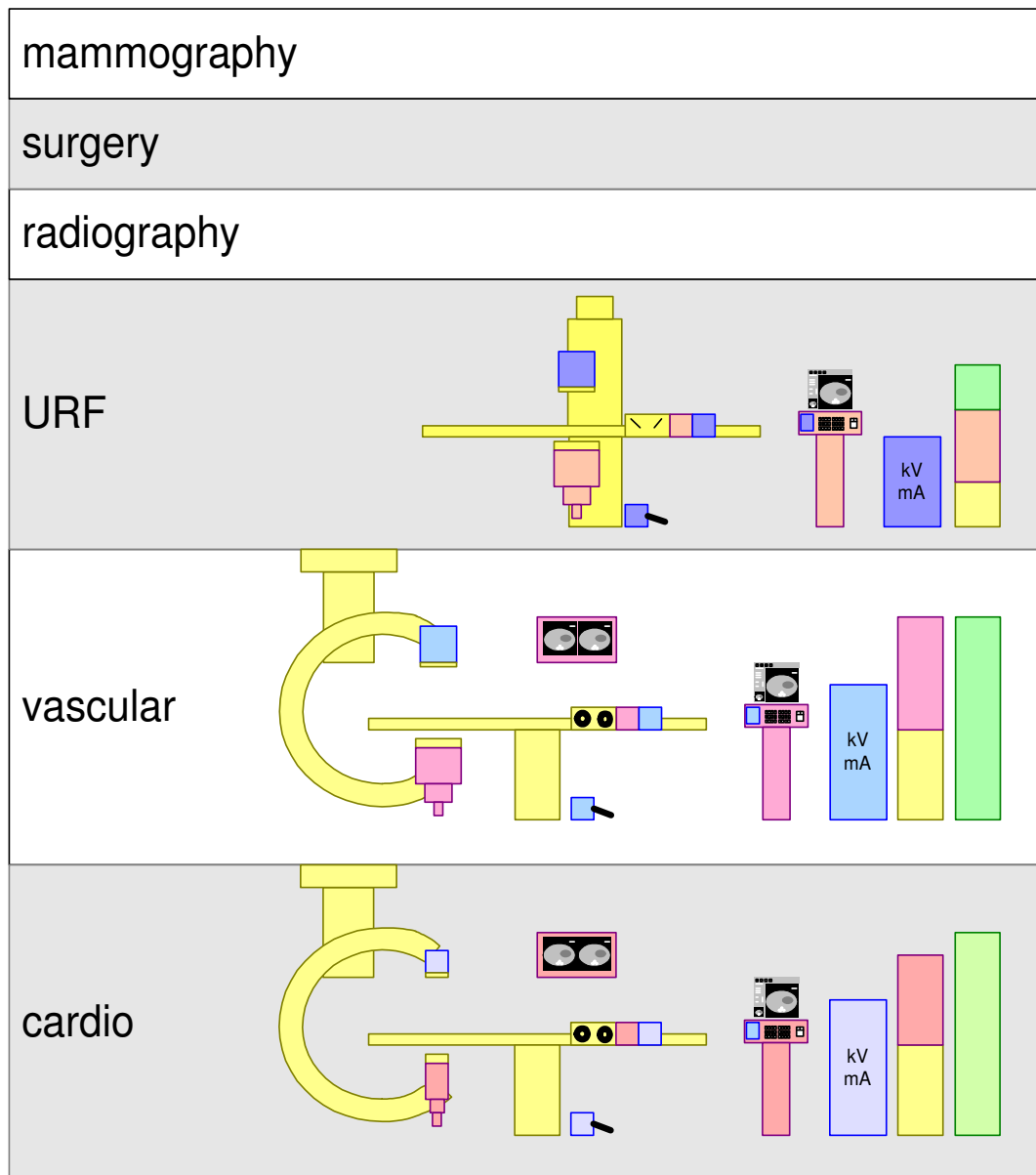
SW in all subsystems

SI is electro mechanical *and configuration parameters*

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

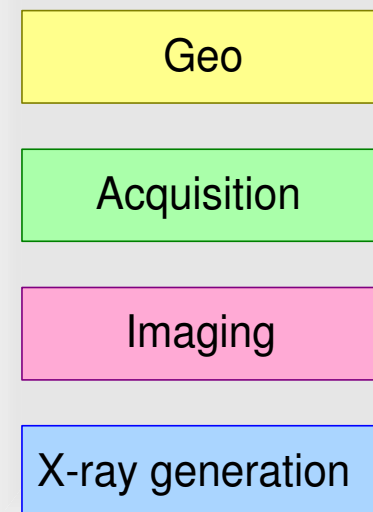


# Organization in 1985: Product/Business Oriented



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

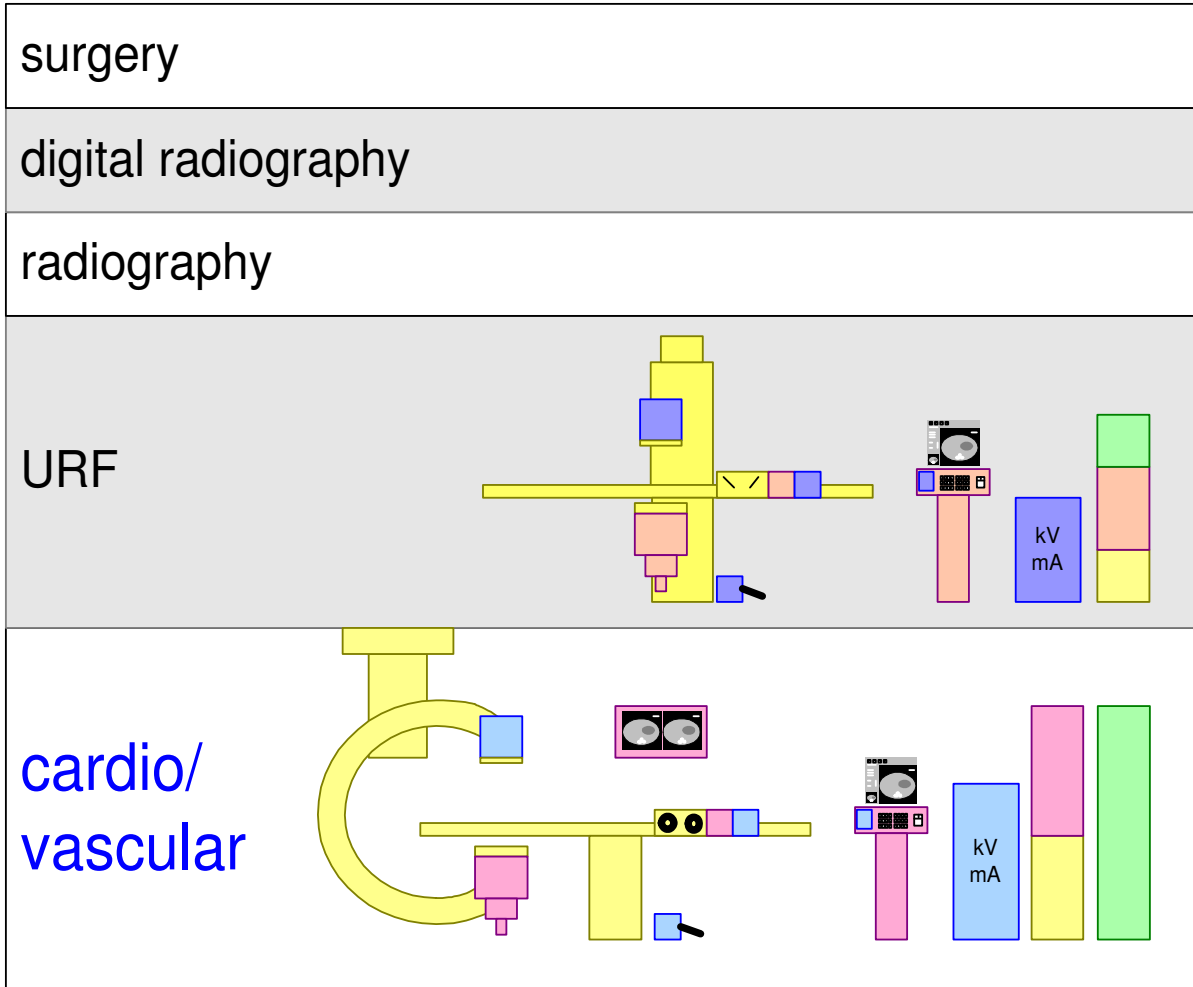
legend





# Synergy drive ca 1990

Cardio and Vascular are merged. Digital imaging gets dominant



legend

Geo

Acquisition

Imaging

X-ray generation

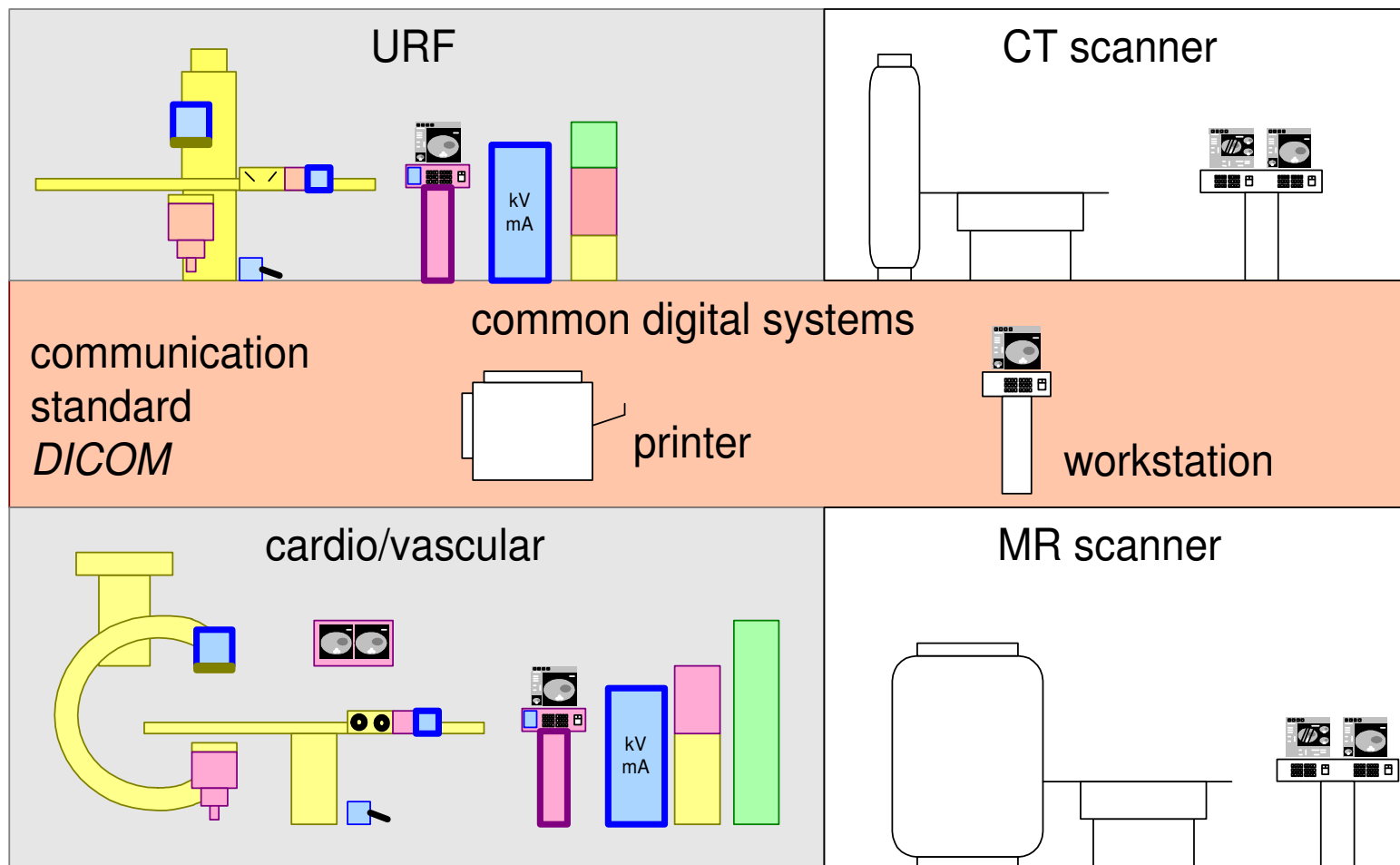




# System: 1995..2000 Synergy Drive

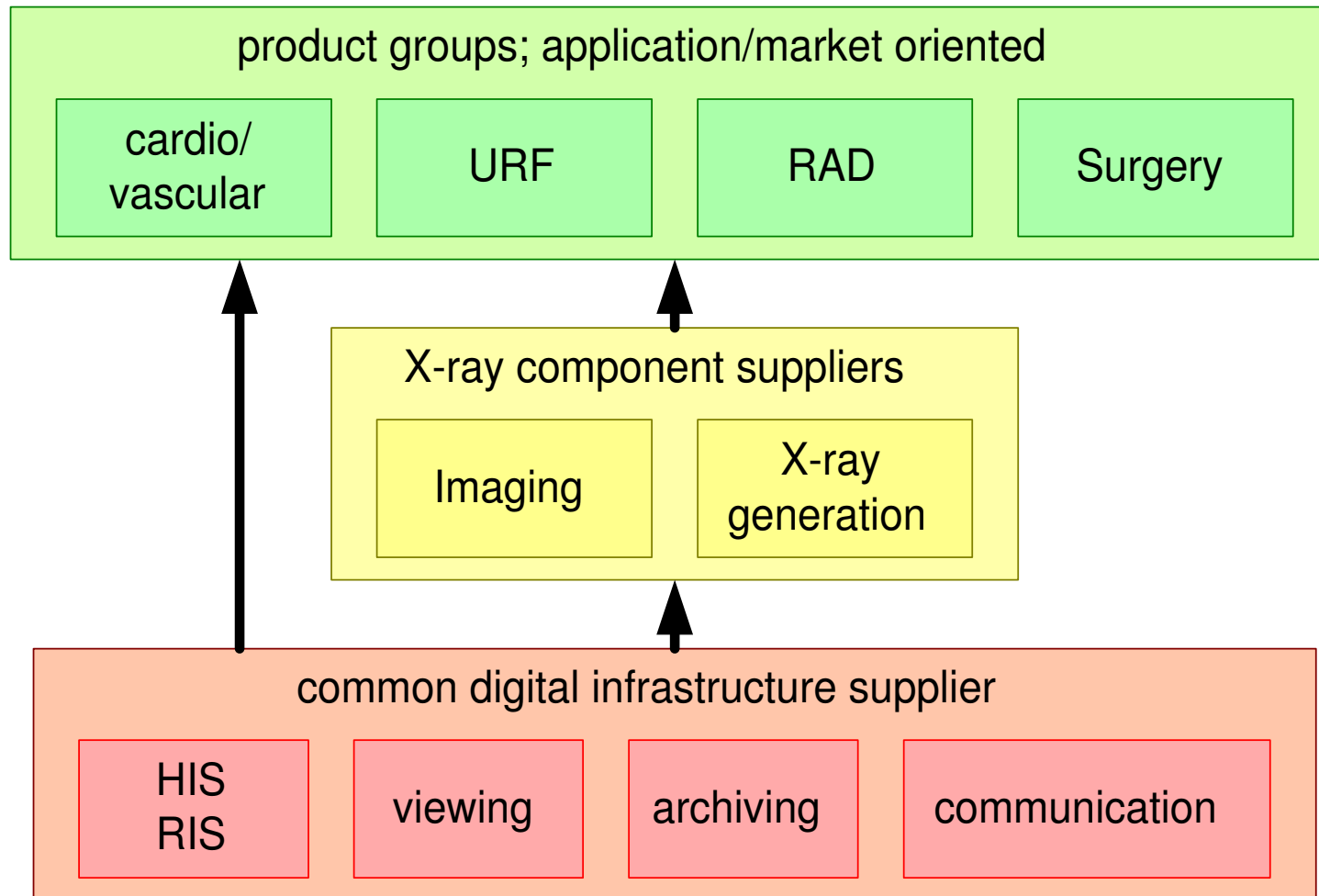
Common X-ray components (imaging, generation, collimators)

Common digital infrastructure (workstations, networks, printers)



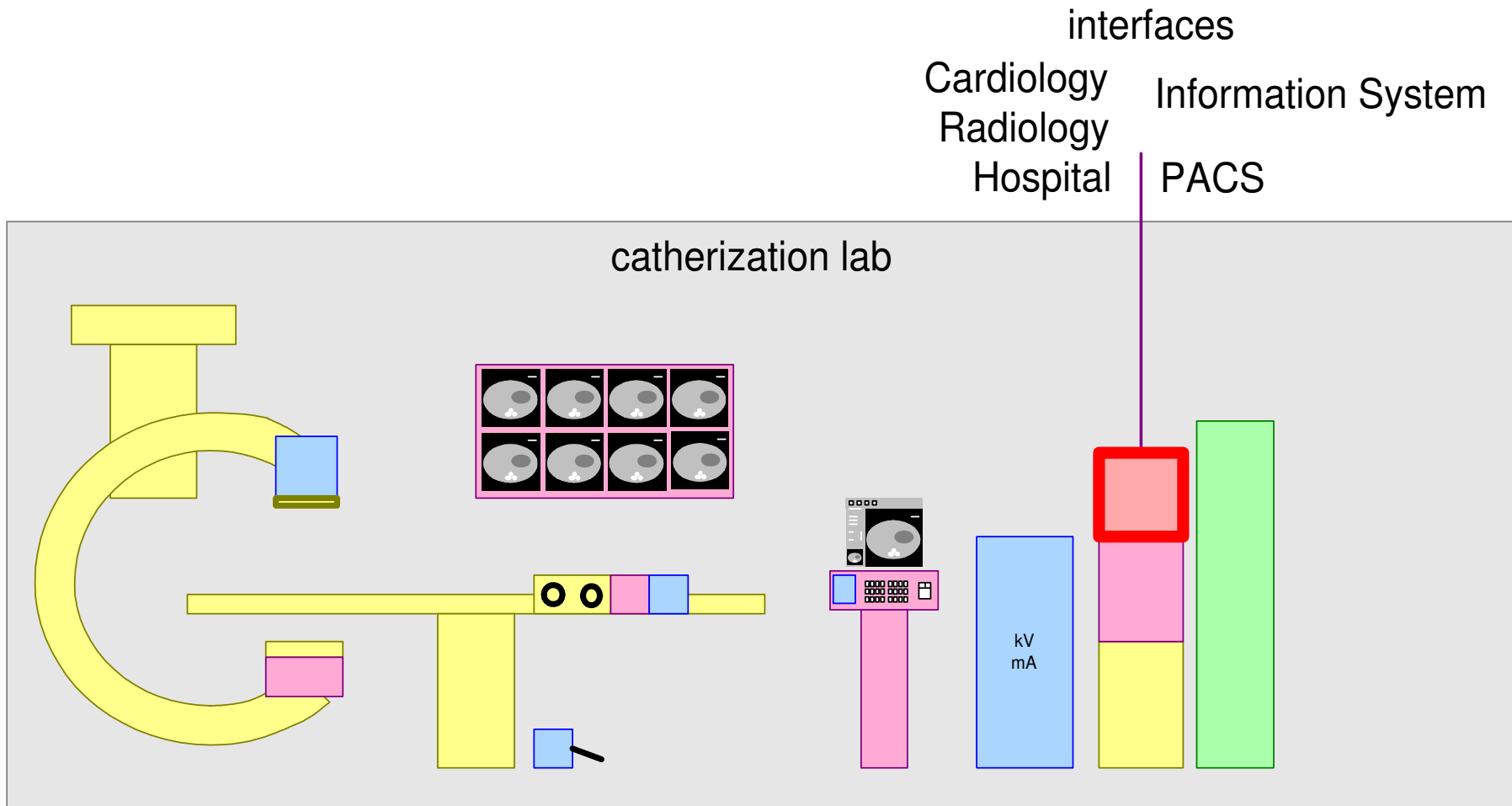
# Organization 1995..2000: Additional Synergy Layer

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



# 2000: Introduction of central System Control

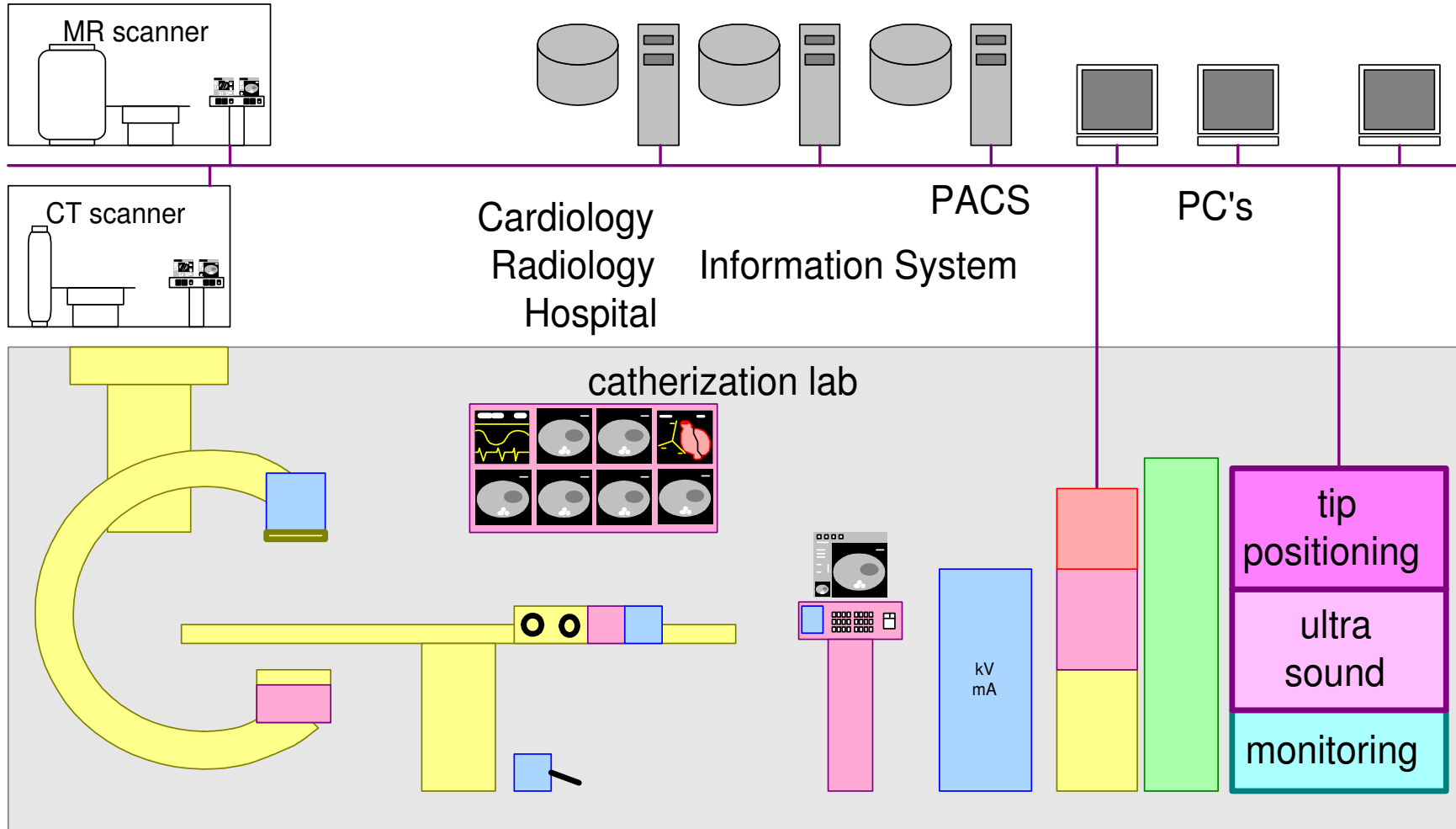
New: system control = industrial PC + Windows XP + **4 Mloc** + 3rd party SW



# System: 2005 System of Systems?

Catherization Laboratory integrates many systems

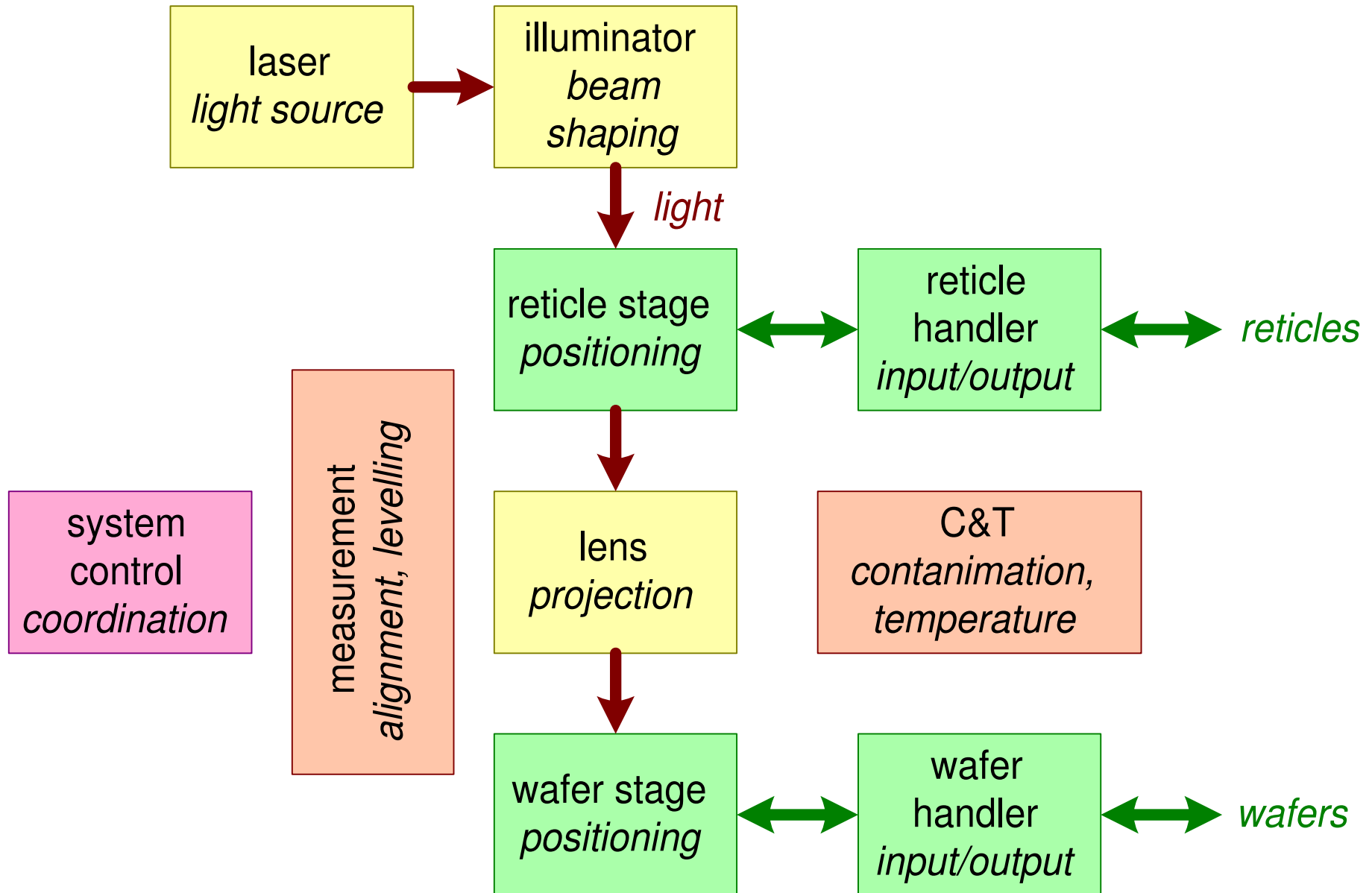
and is heavily connected to other health care departments and systems



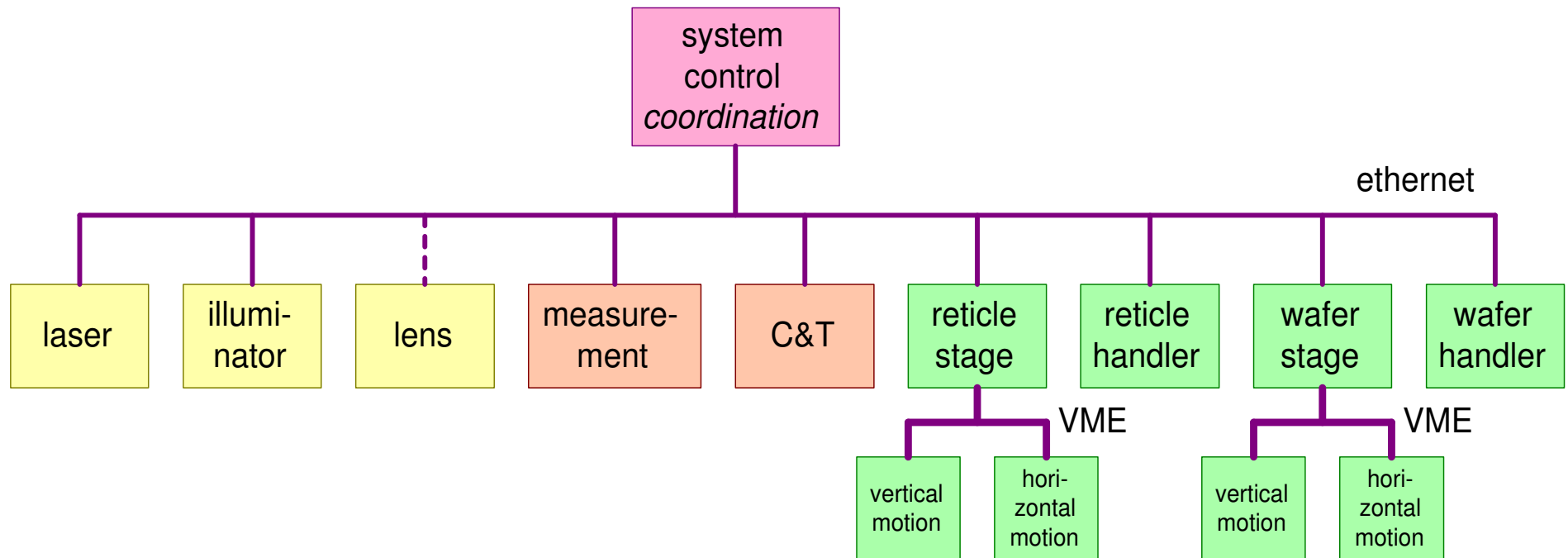
# Characterization per Phase

	<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>	

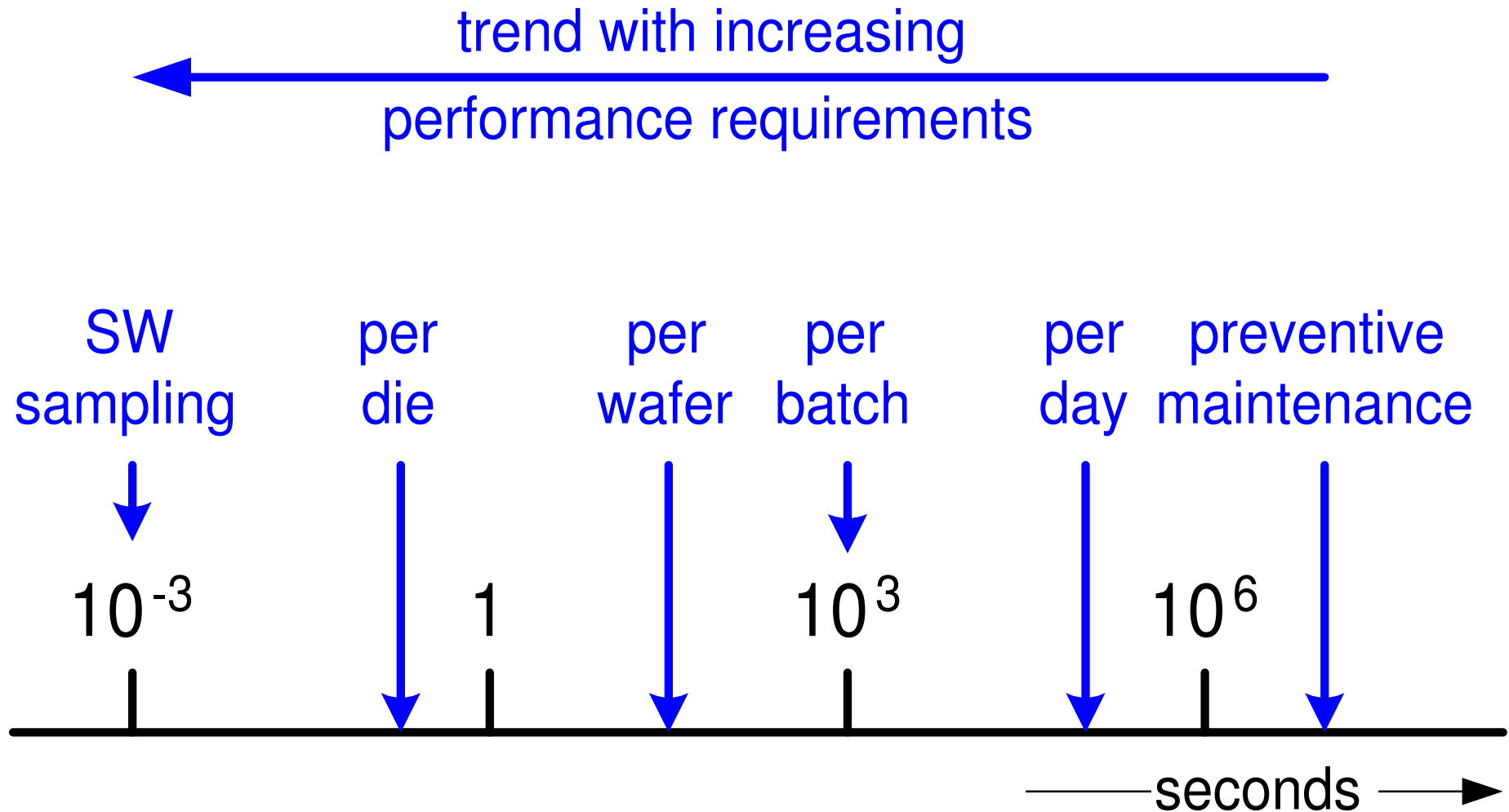
# Block Diagram of a Waferstepper



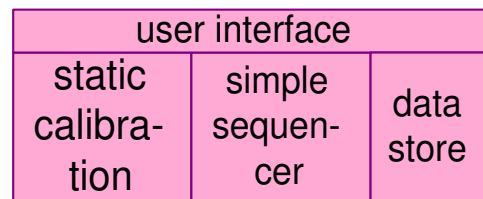
# Control Hierarchy of a Waferstepper



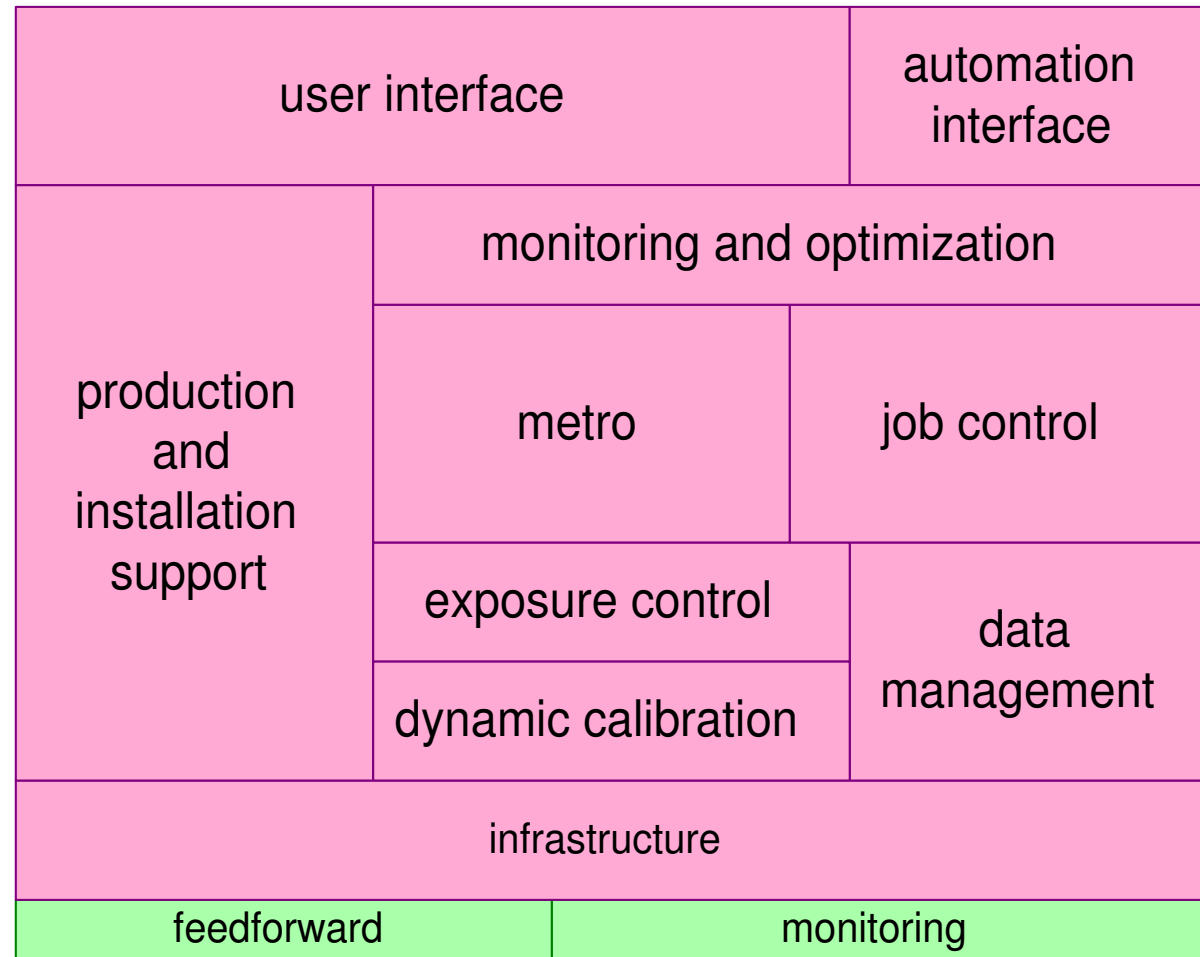
# Frequency of Control Actions



# Evolution of System Control

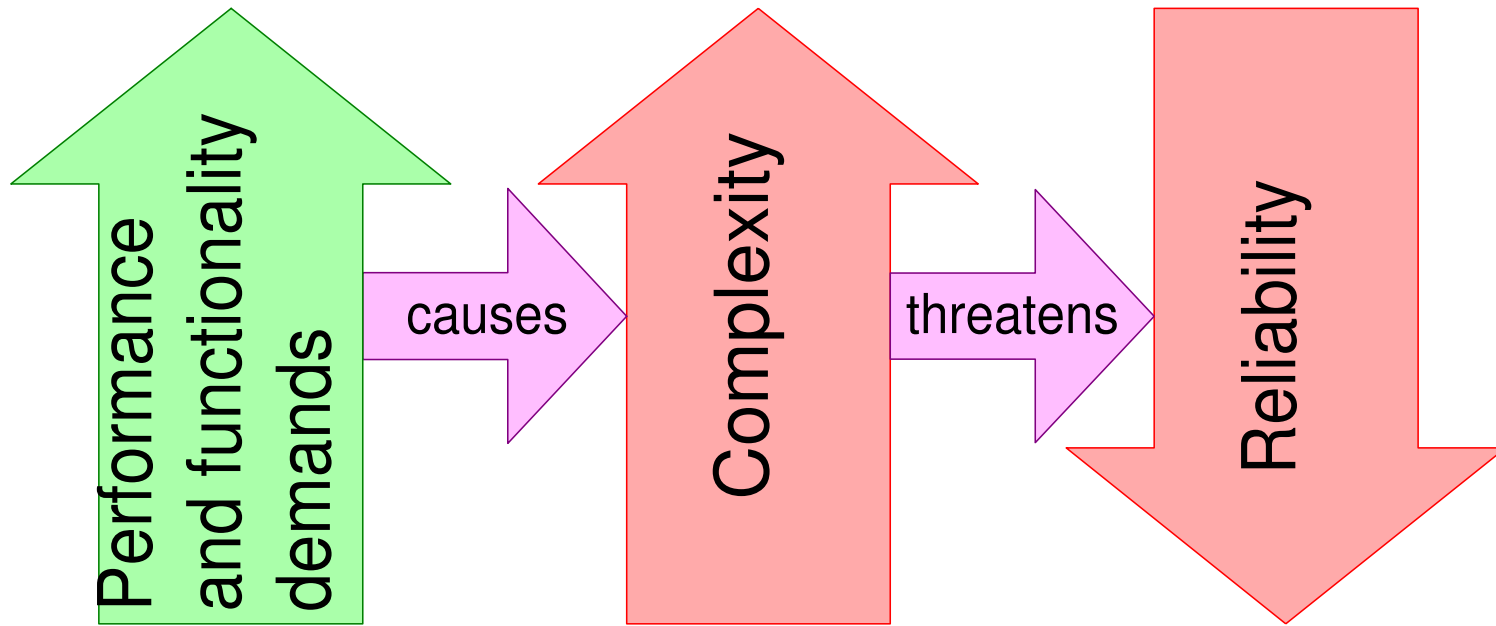


1990  
150 kloc



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

*autonomous subsystems* ———— paradigm shift! ———— *integrated system*