From Autonomous Subsystems to Integrated System

by *Gerrit Muller* University of South-Eastern Norway-NISE
e-mail: gaudisite@gmail.com
www.gaudisite.nl

Abstract

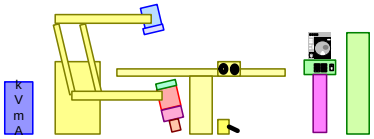
Systems evolve from mostly mechanical or physical devices into multi-disciplinary integrated systems. This evolution takes years or decades. The evolution occurs simultaneously with changes in the markets and in the organization. We describe this evolution and illustrate it with a X-ray systems and wafersteppers.

December 1, 2022
status: planned
version: 0.1

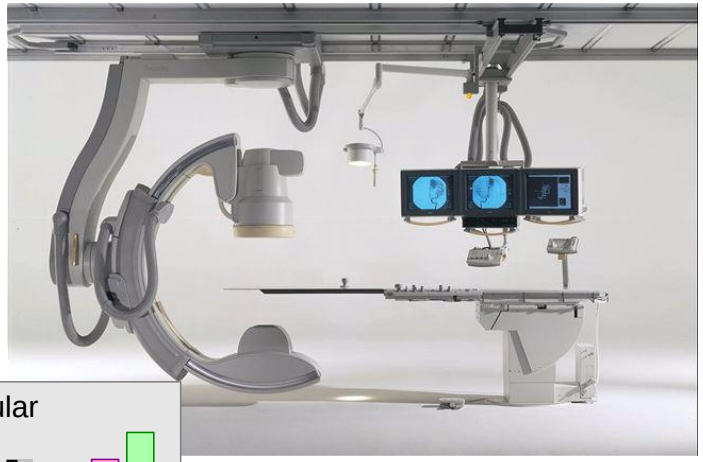
logo
TBD

Evolution of X-ray Systems

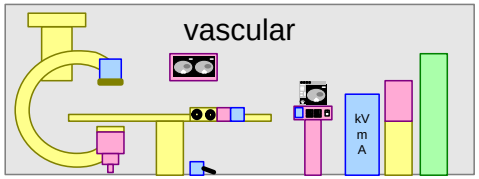
1980 1985 1990 1995 2000 2005



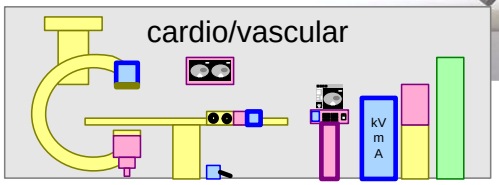
electro-mechanical components



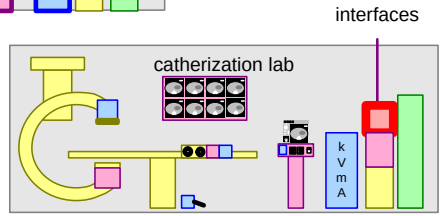
autonomous subsystems



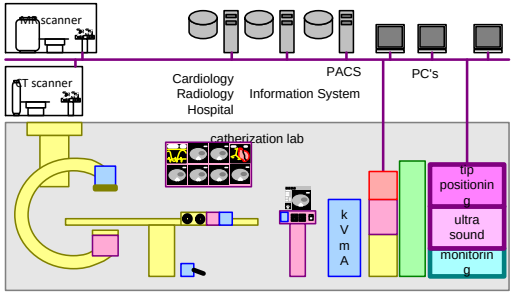
synergy



system control

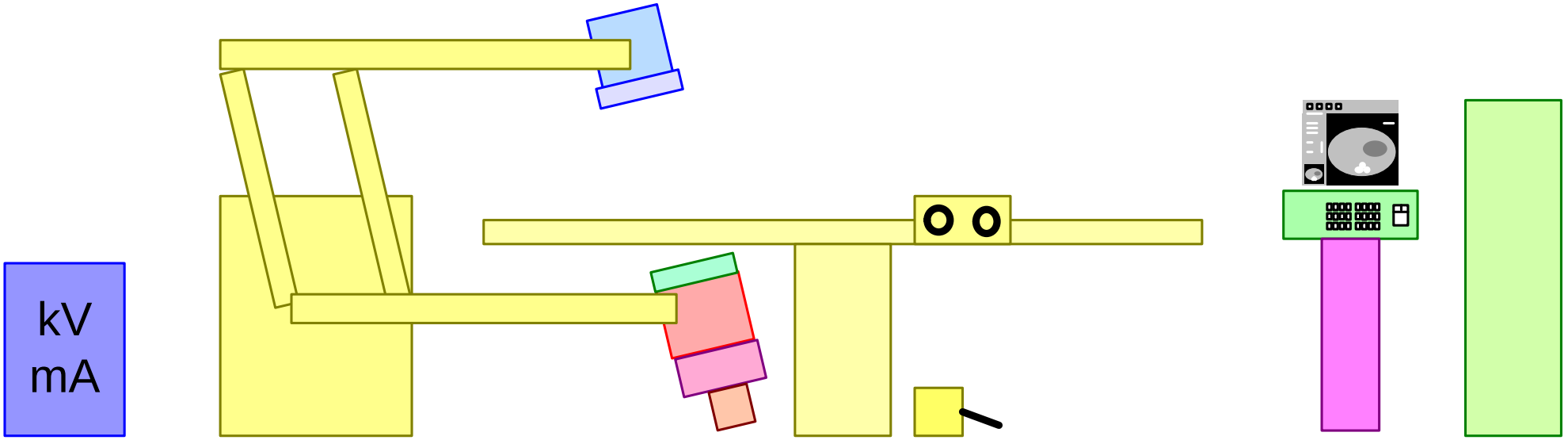


system of systems

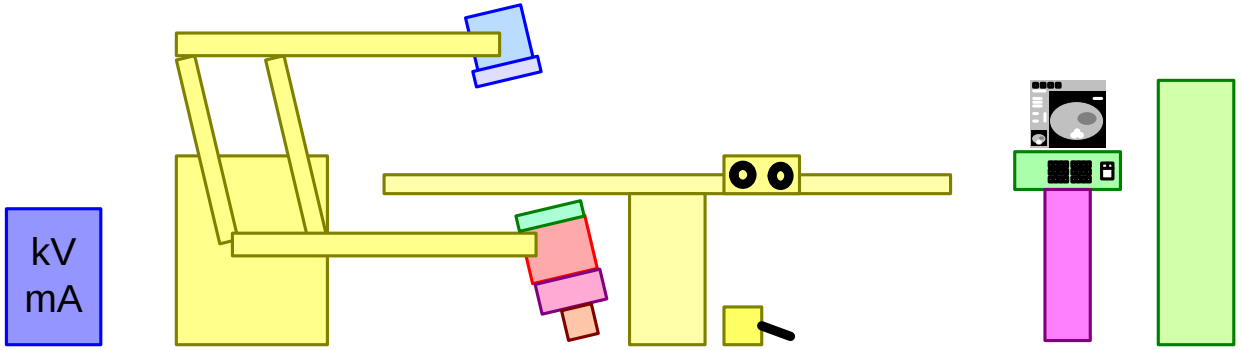


Diagnostic X-ray system 1980

..~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

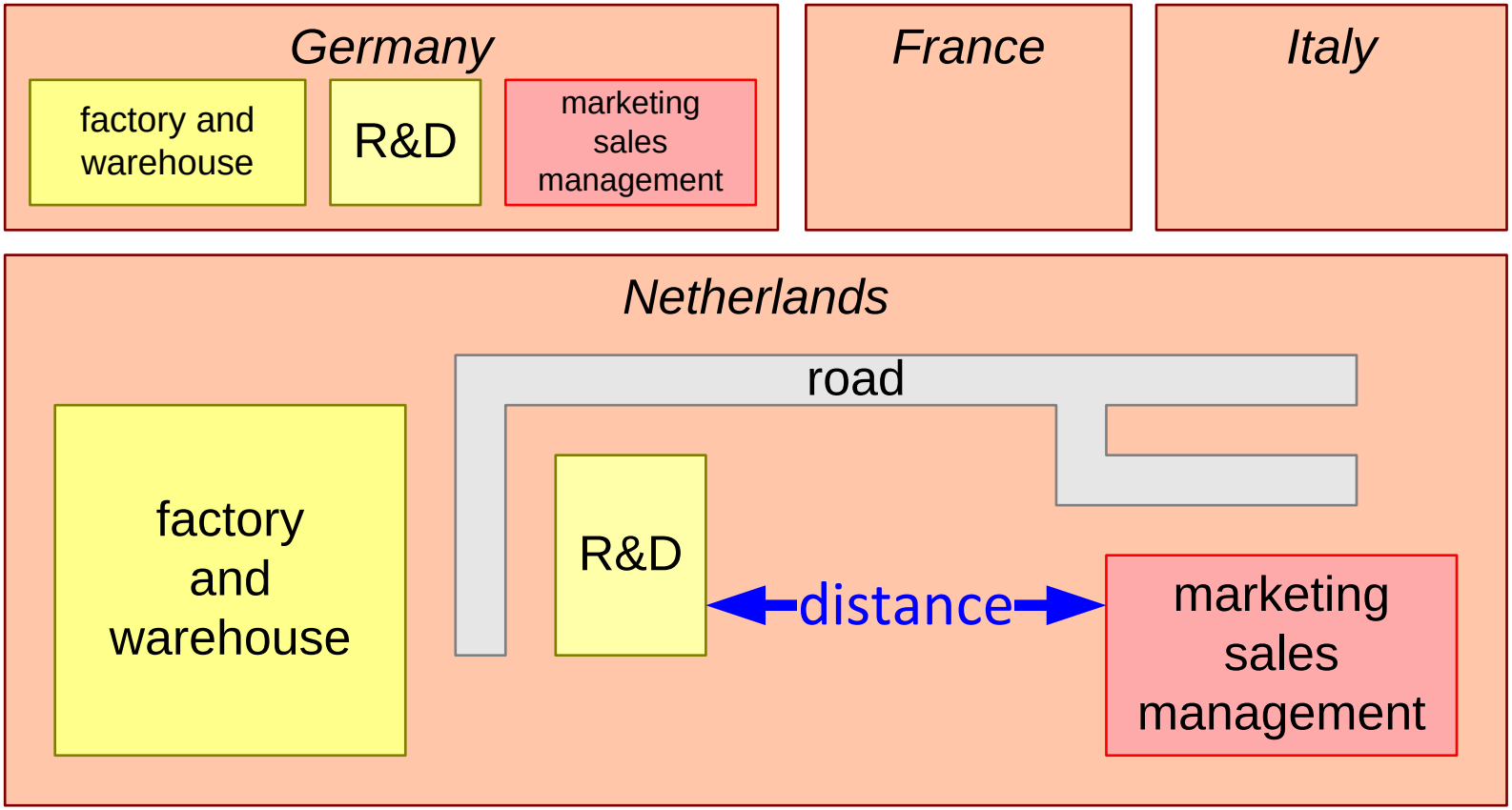
Roentgen Electronics Laboratory

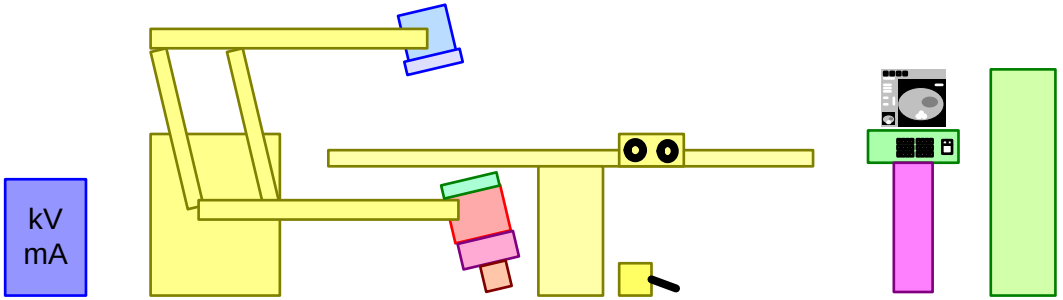
Mechanical Electronics Laboratory

Physics Technical Laboratory

facilitating departments: drawing office; construction office; workshops

Geographical locations in 1980





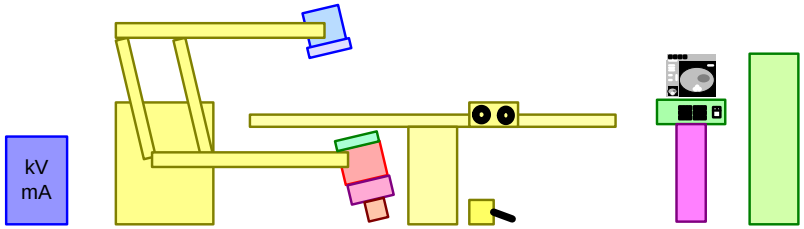
Staff in 1980

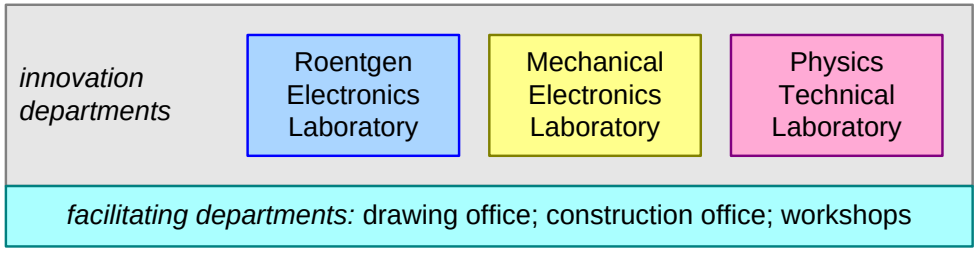
small teams

3 key persons:
- application
- senior designer
- cardiologist (outside Philips)

application and domain technology implicit in most staff

staffing mostly domain technology driven

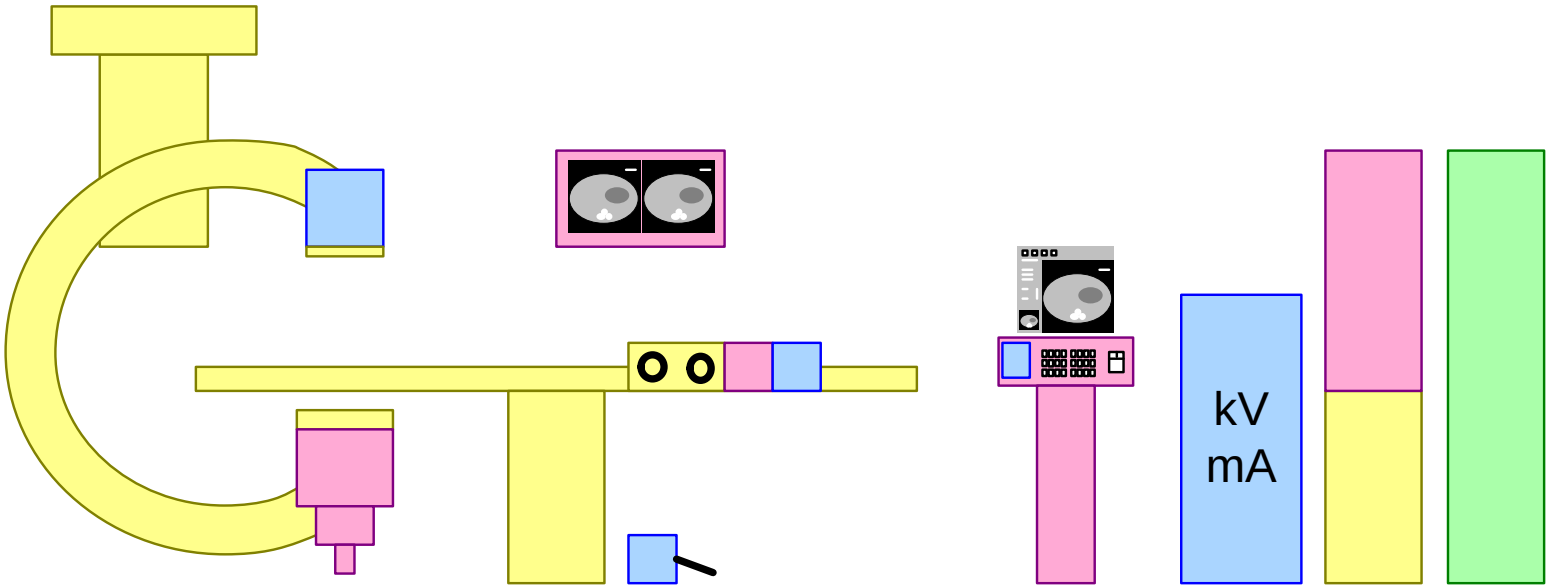




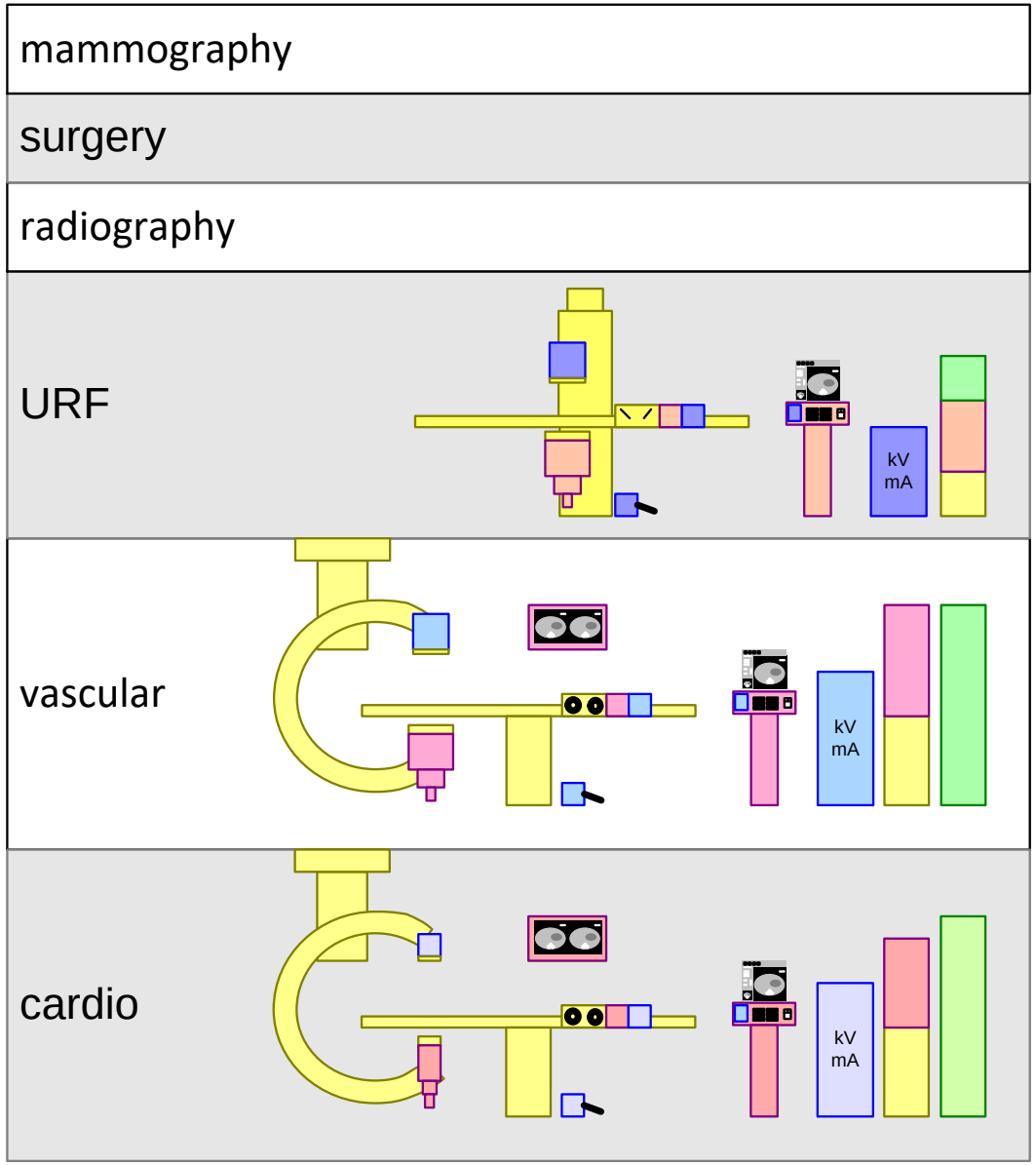
Systems 1985..1995

..~1985
autonomous subsystems: Geo | Acquisition | Imaging | X-ray generation

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

Geo

Acquisition

Imaging

X-ray generation

Staff in 1985

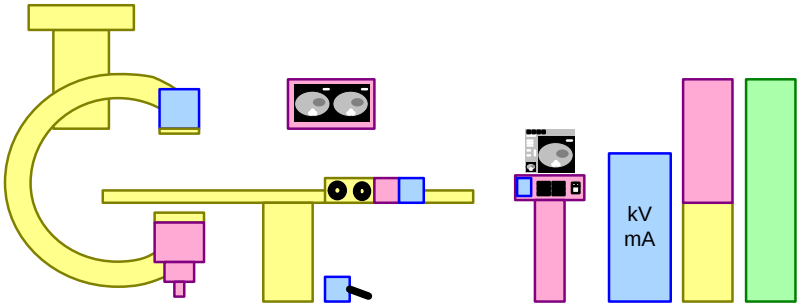
medium sized teams

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

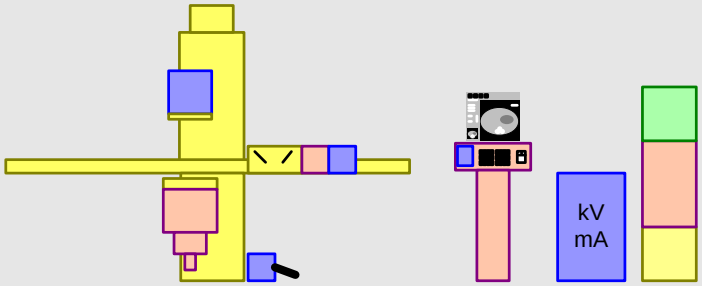
Cardio and Vascular are merged. Digital imaging gets dominant

surgery

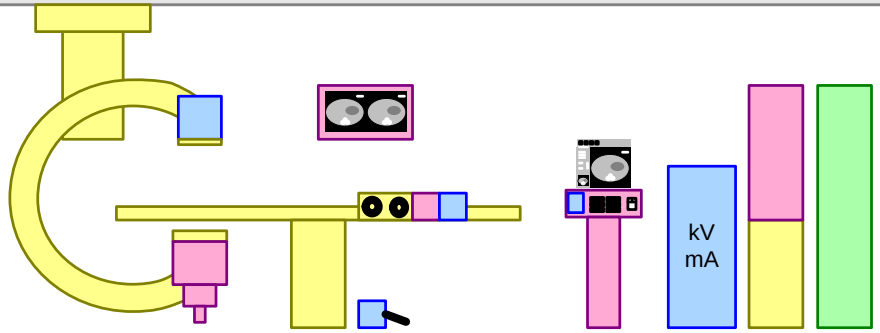
digital radiography

radiography

URF



cardio/
vascular



legend

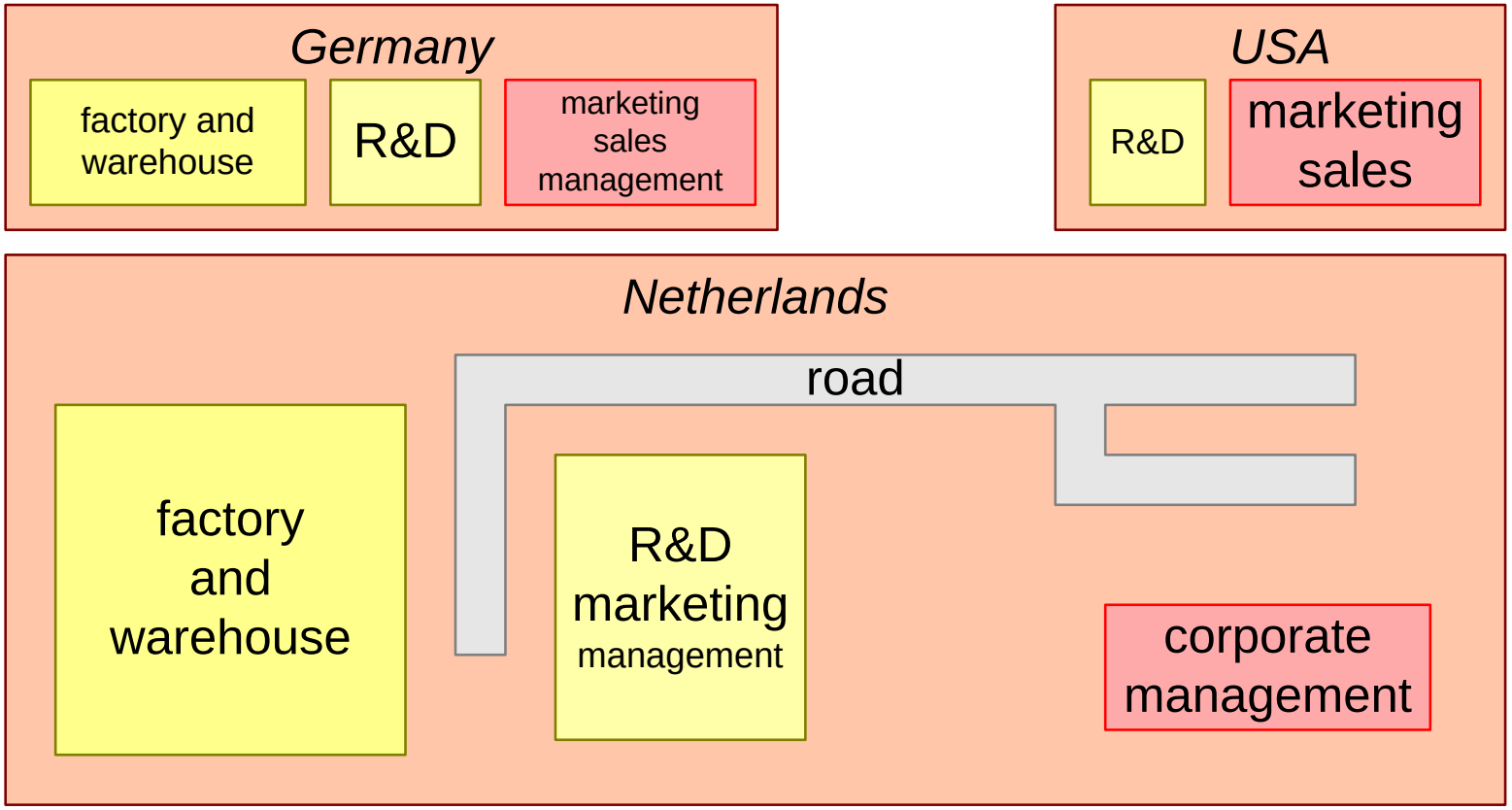
Geo

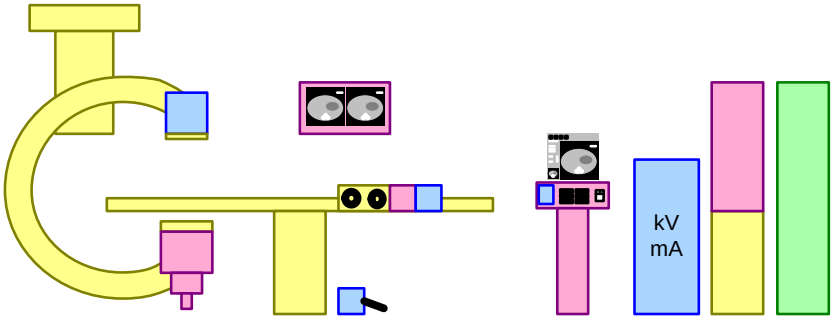
Acquisition

Imaging

X-ray generation

Geographical locations in 1990





Staff in 1990

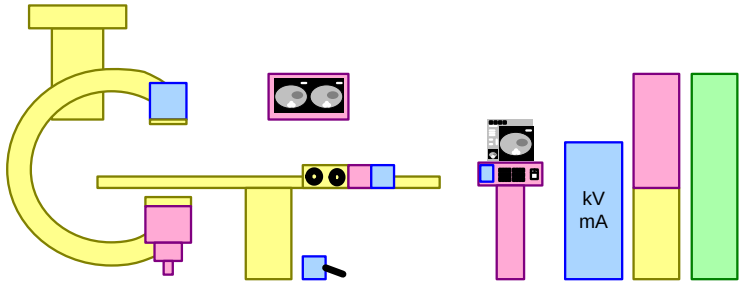
matrix organizations within product groups:
- mechanical
- electrical
- software

application and domain technology know how diluted

software content is significant

test and validation time is significant (> 1 year)

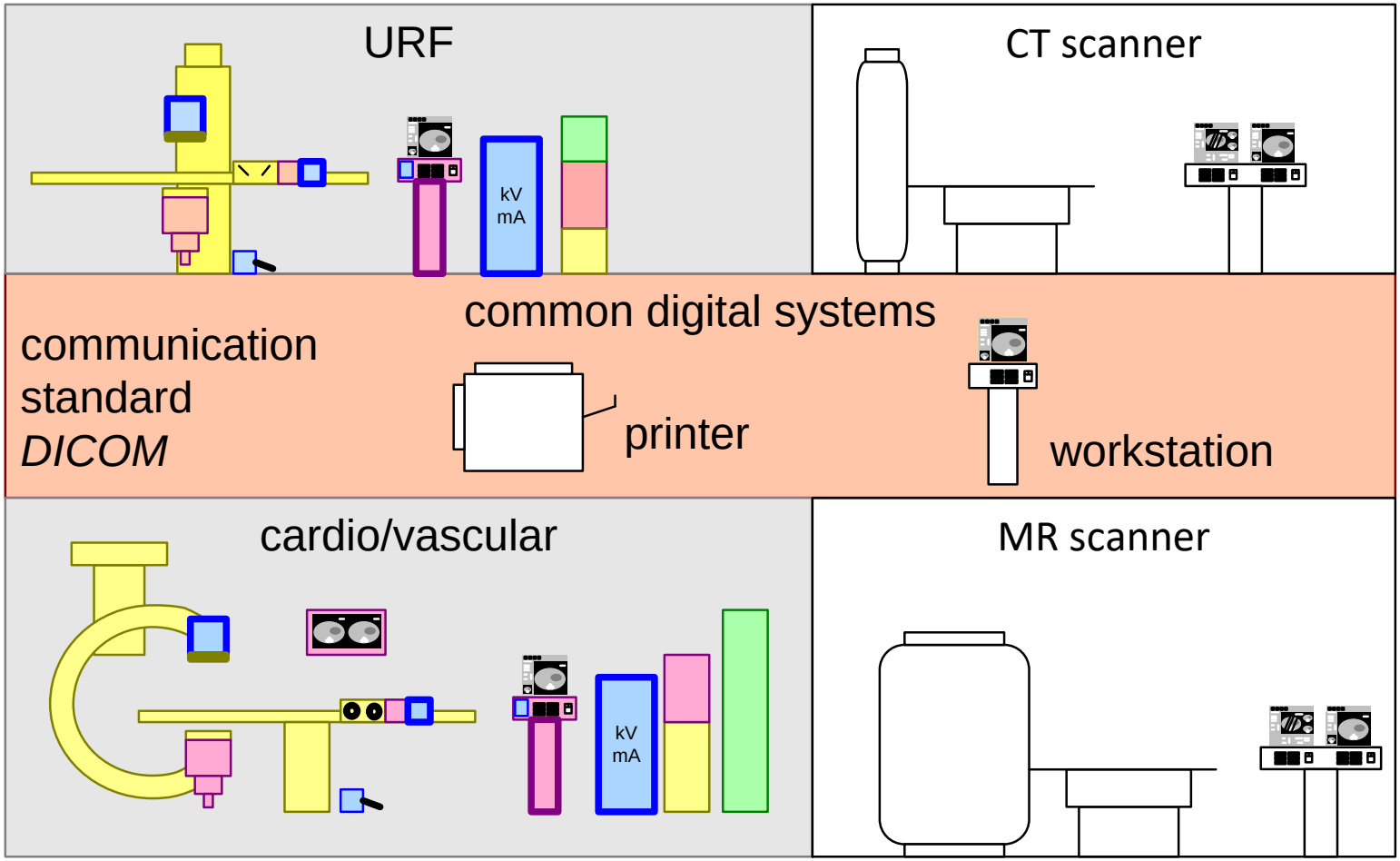
senior designer ~= system designer



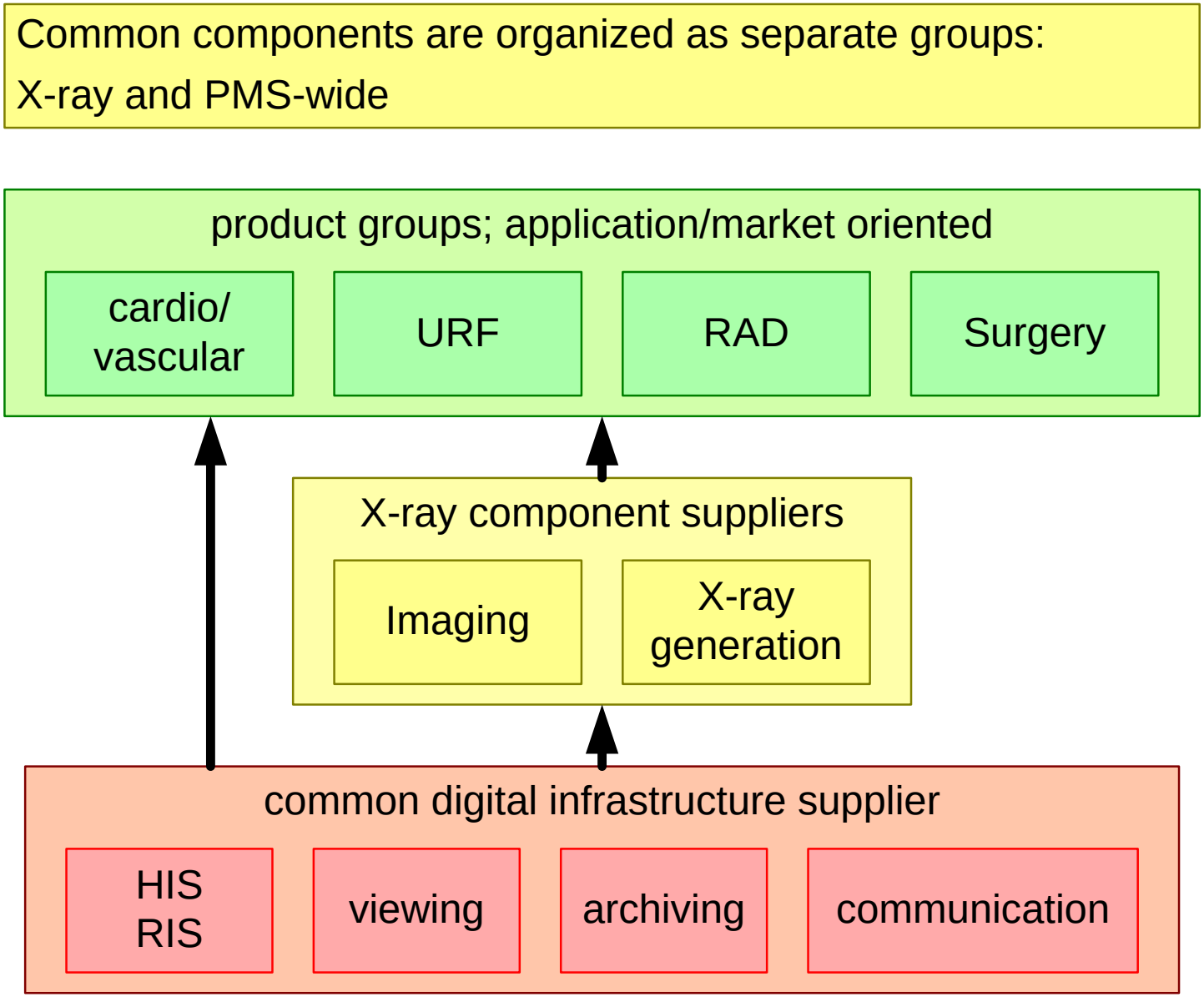
System: 1995..2000 Synergy Drive

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

Common digital infrastructure (workstations, networks, printers)

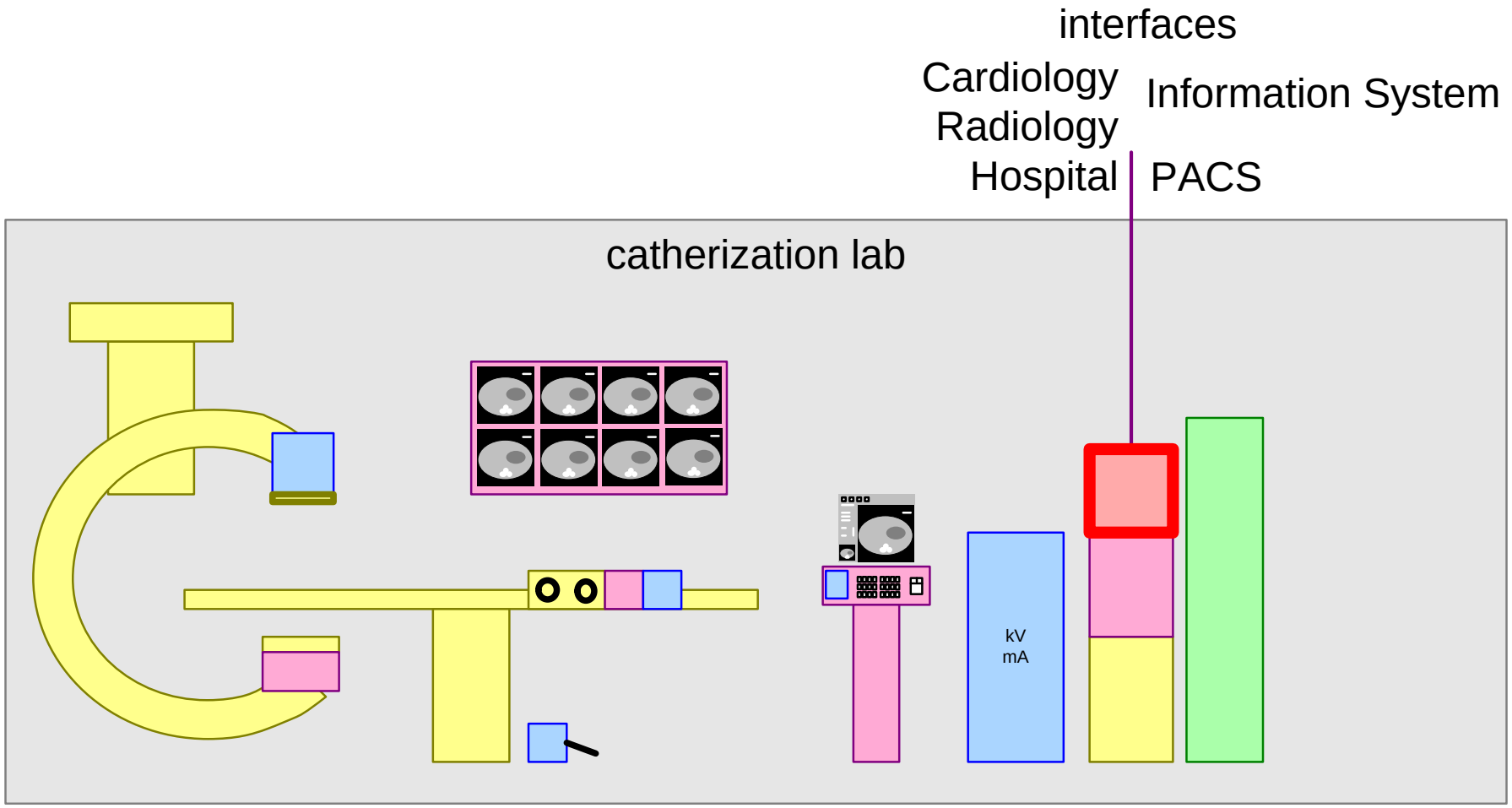


Organization 1995..2000: Additional Synergy Layer



2000: Introduction of central System Control

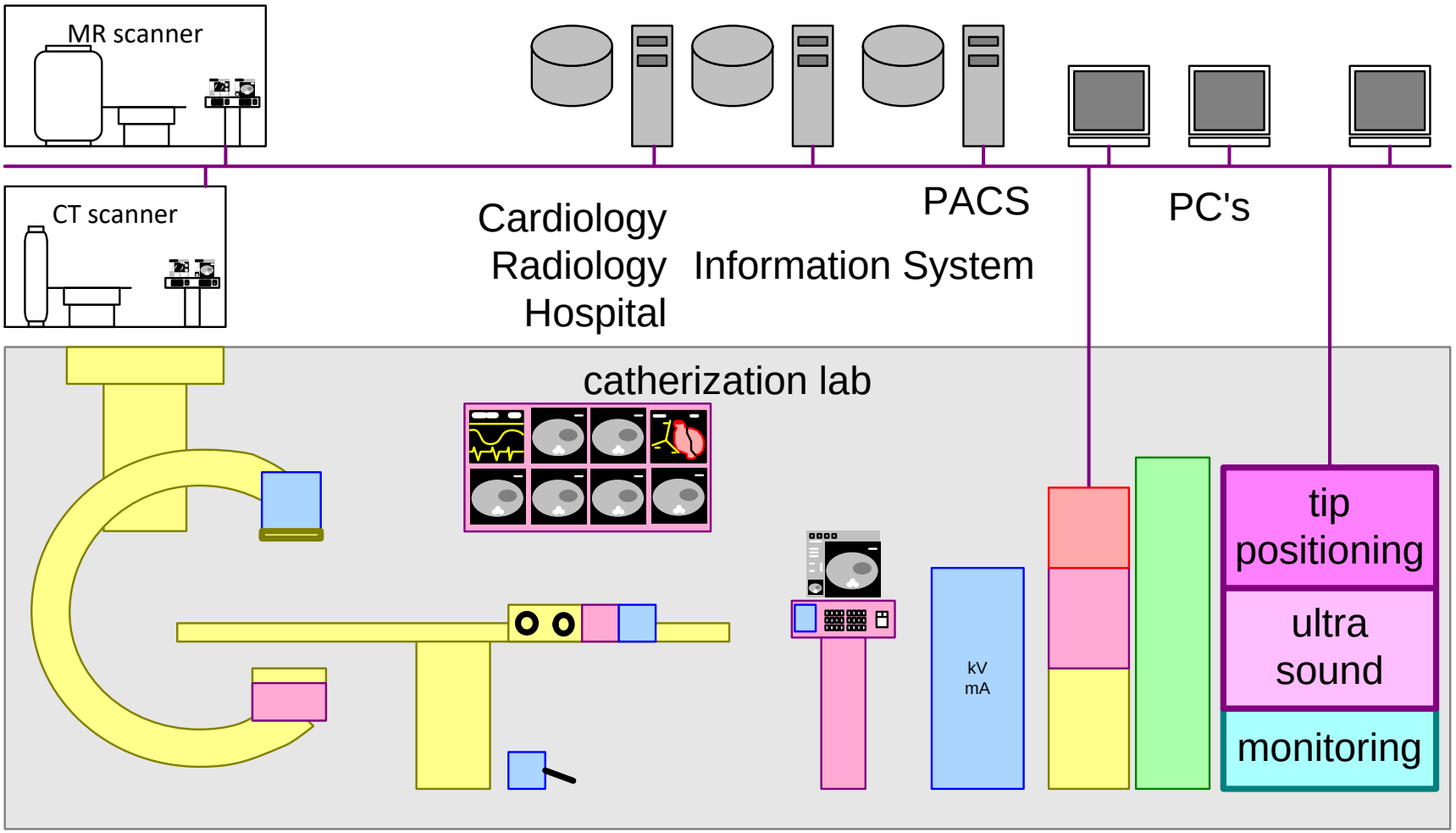
New: system control = industrial PC + Windows XP + **4 Mloc** + 3rd party SW



System: 2005 System of Systems?

Catherization Laboratory integrates many systems

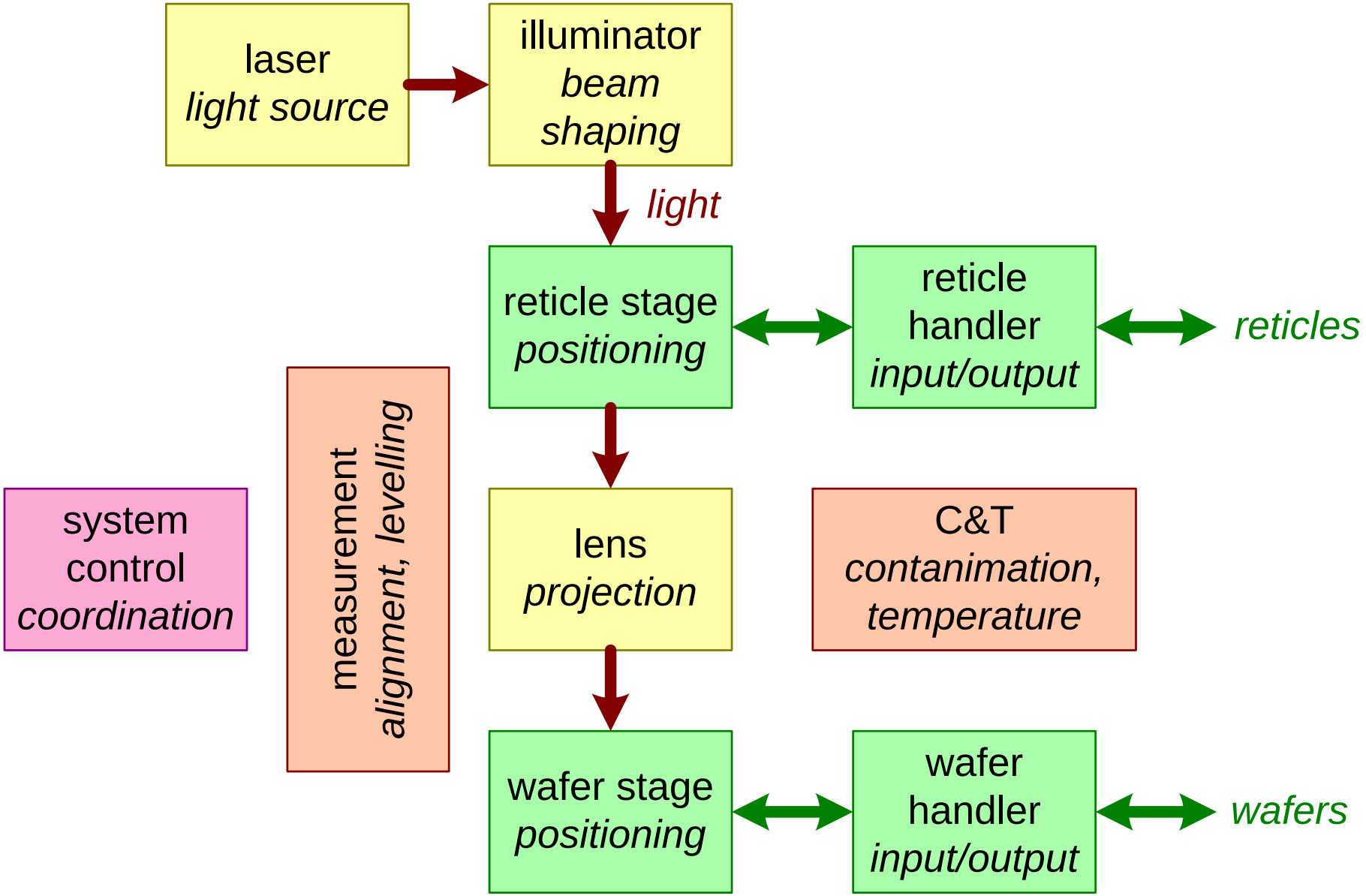
and is heavily connected to other health care departments and systems



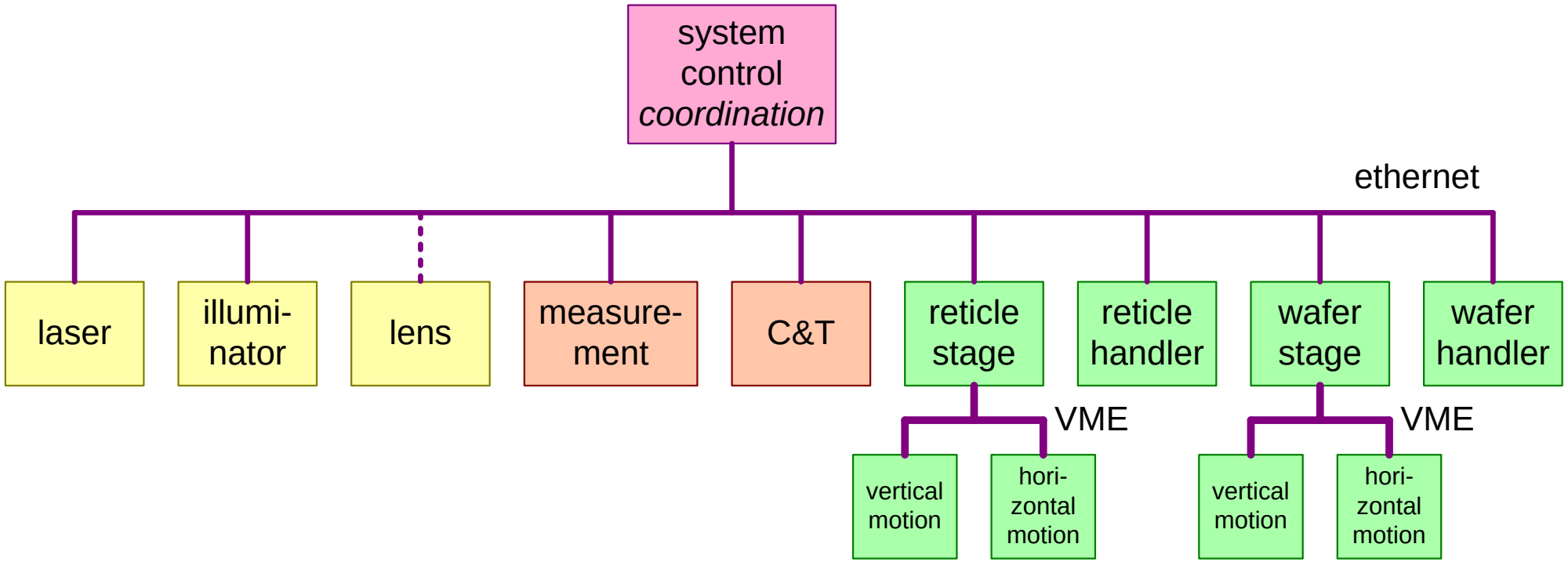
Characterization per Phase

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

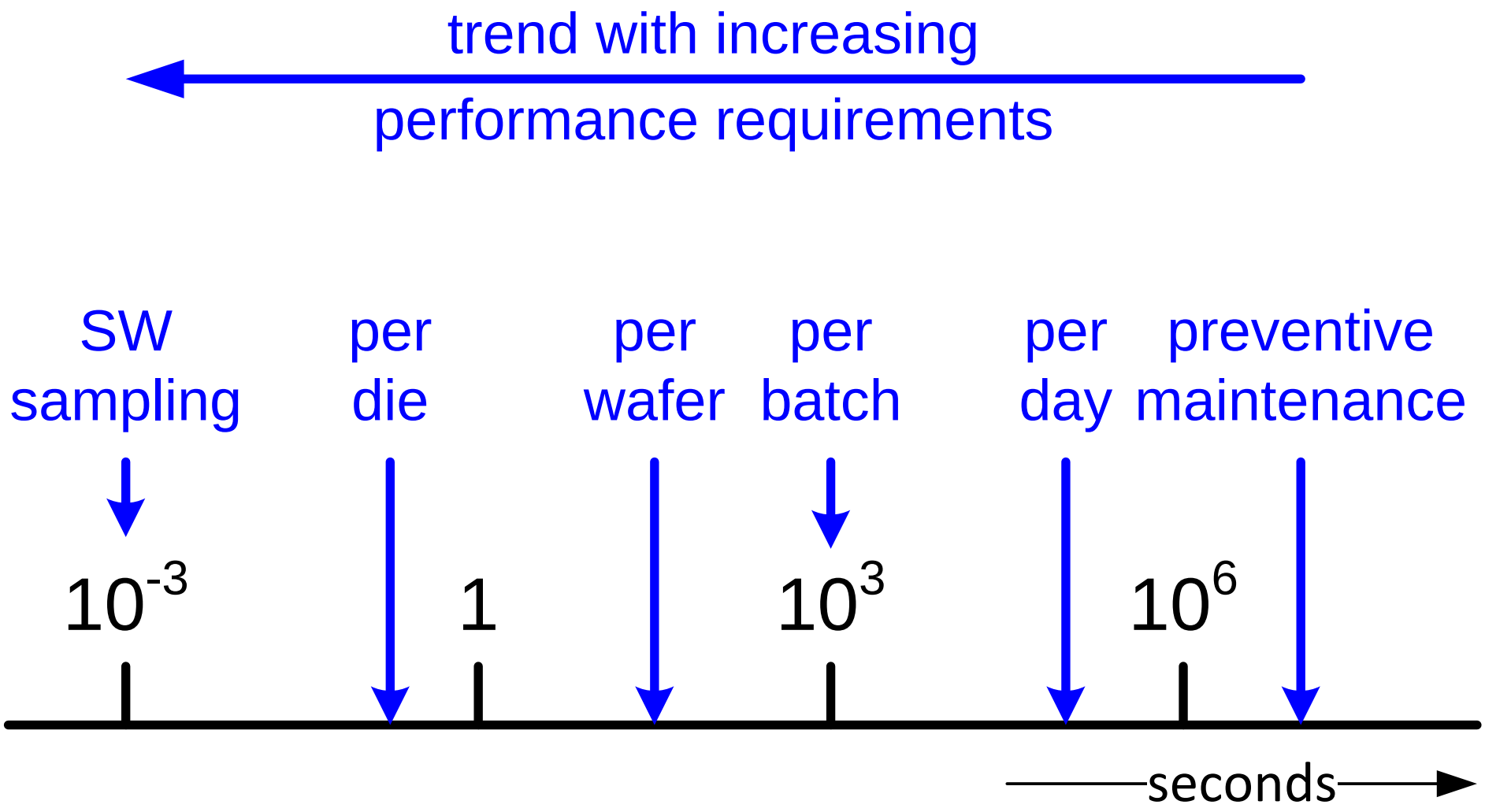
Block Diagram of a Waferstepper



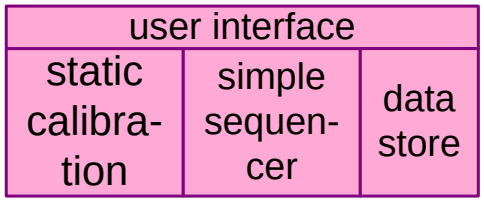
Control Hierarchy of a Waferstepper



Frequency of Control Actions

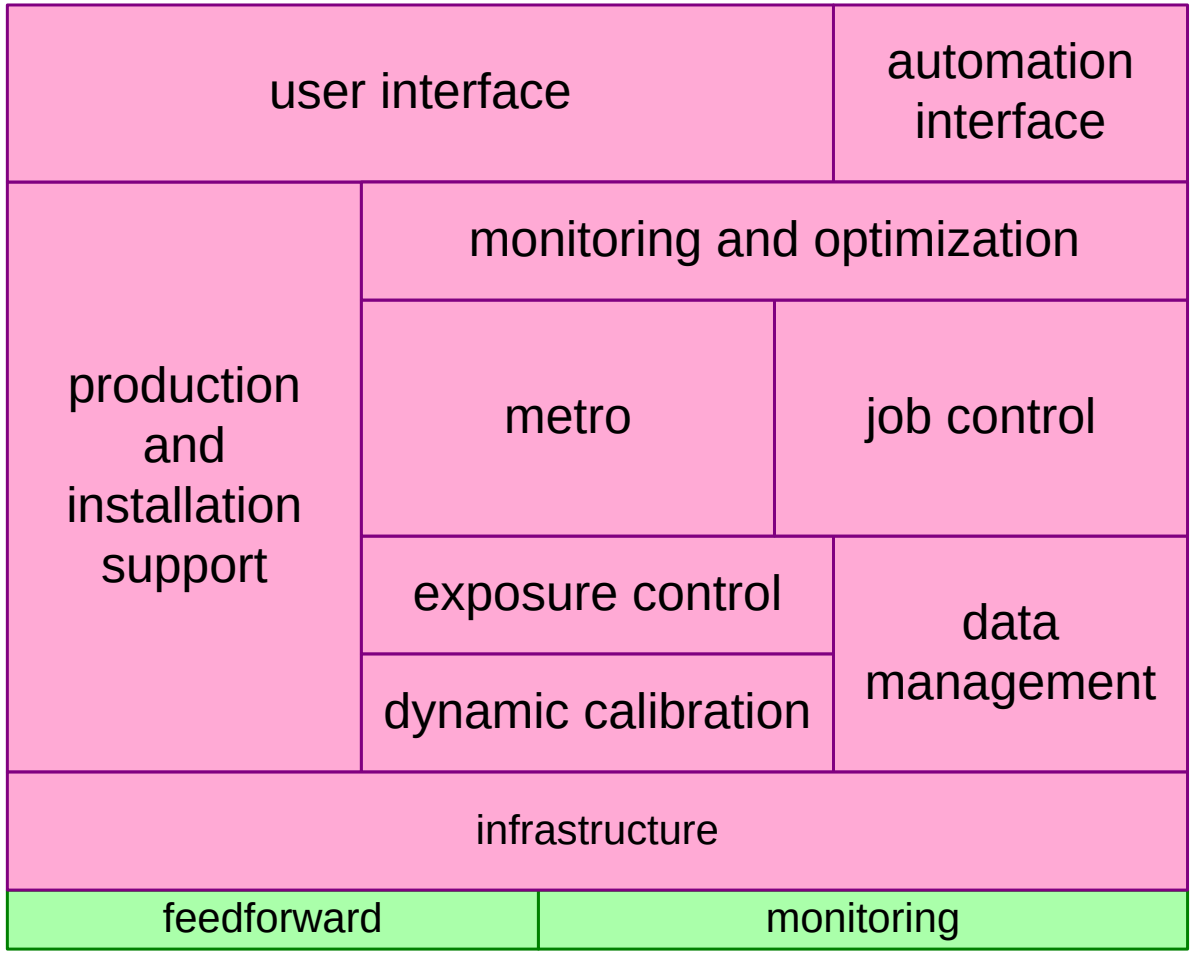


Evolution of System Control



1990

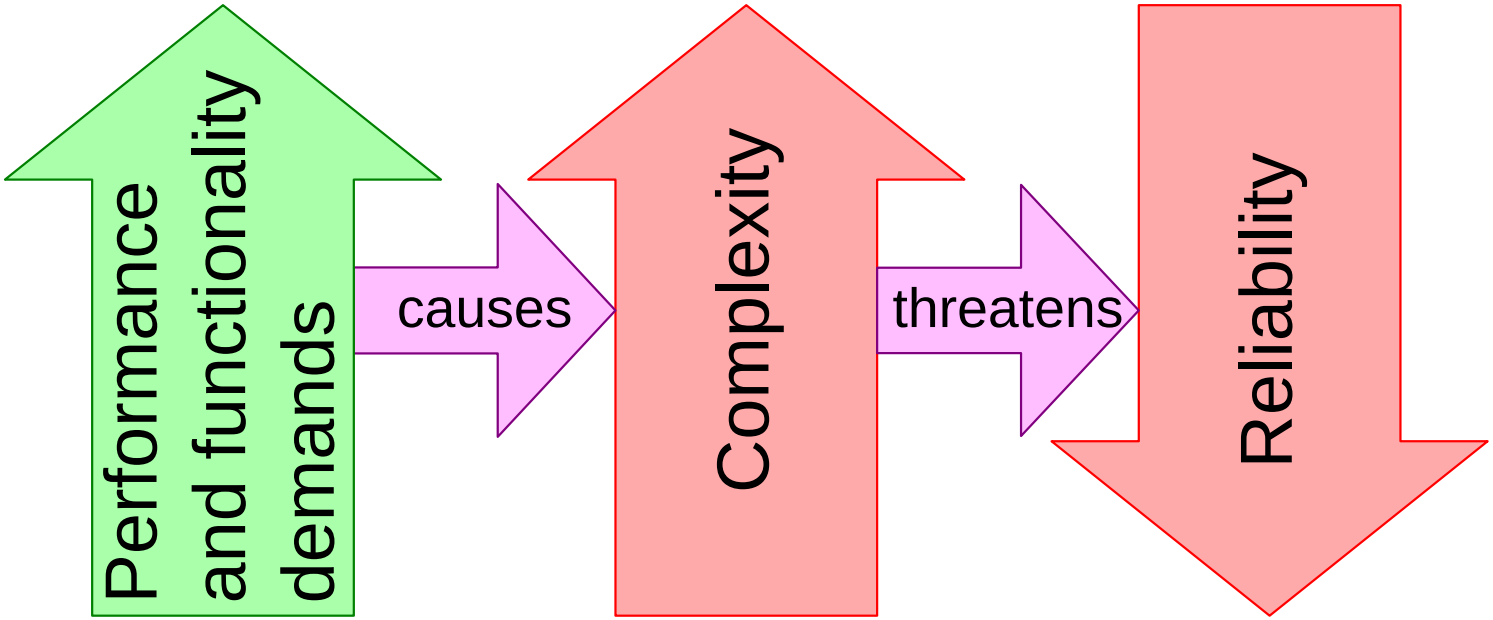
150 kloc



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*