

Module 20 Medical Imaging case, CAFCR illustration

by *Gerrit Muller* University of South-Eastern Norway-NISE

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Abstract

This module provides a complete illustration of the CAFCR based architecting method. The case is a Medical Imaging Workstation, created in the early nineties.

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logo
TBD

Medical Imaging in Chronological Order

by *Gerrit Muller* University of South-Eastern Norway-NISE

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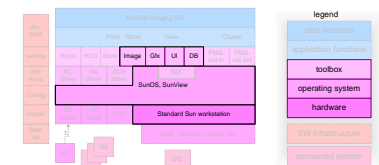
Abstract

The chronological events of the product creation of the medical imaging workstation are discussed. The growth in functionality and size from prototype to product is shown. Typical problems in this period are explained.

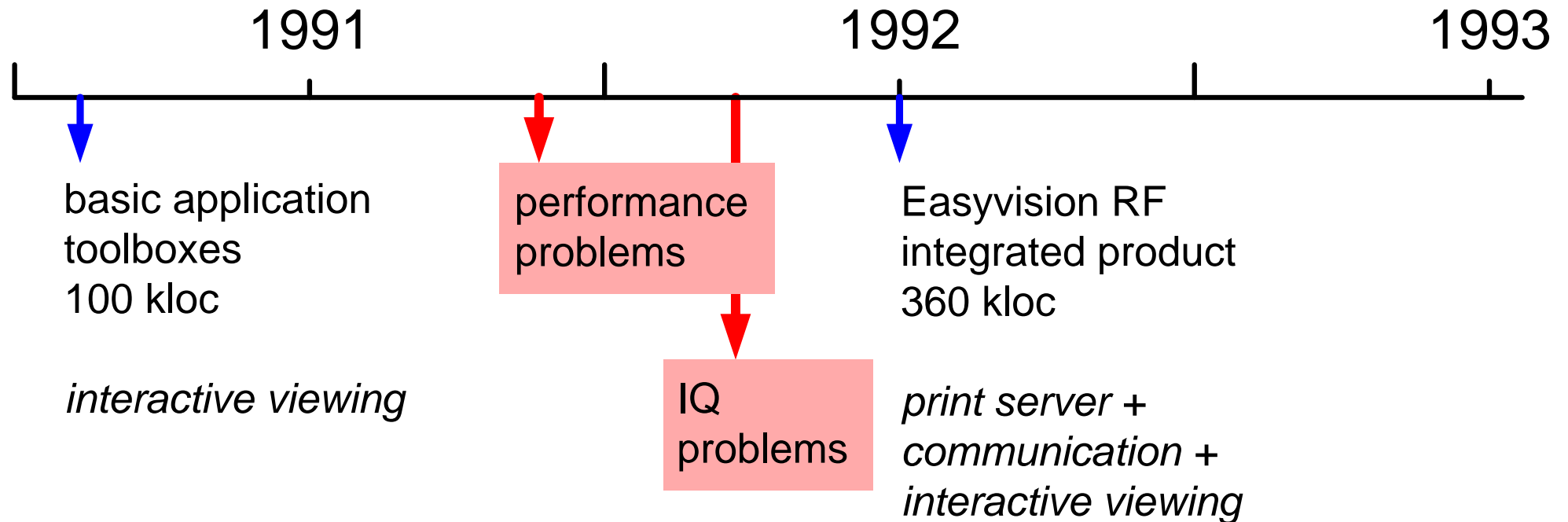
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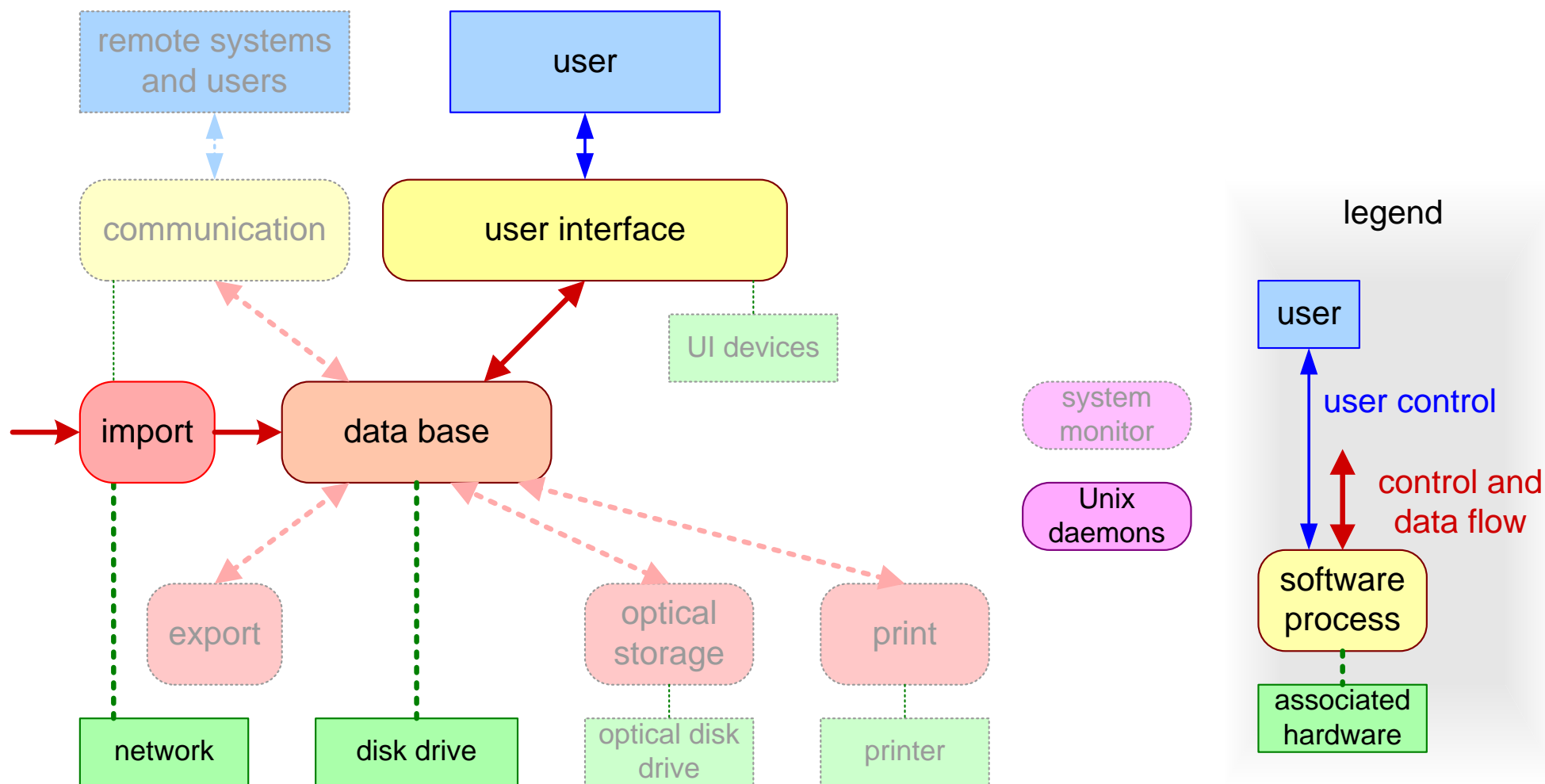
Chronology of Easyvision RF R1 development



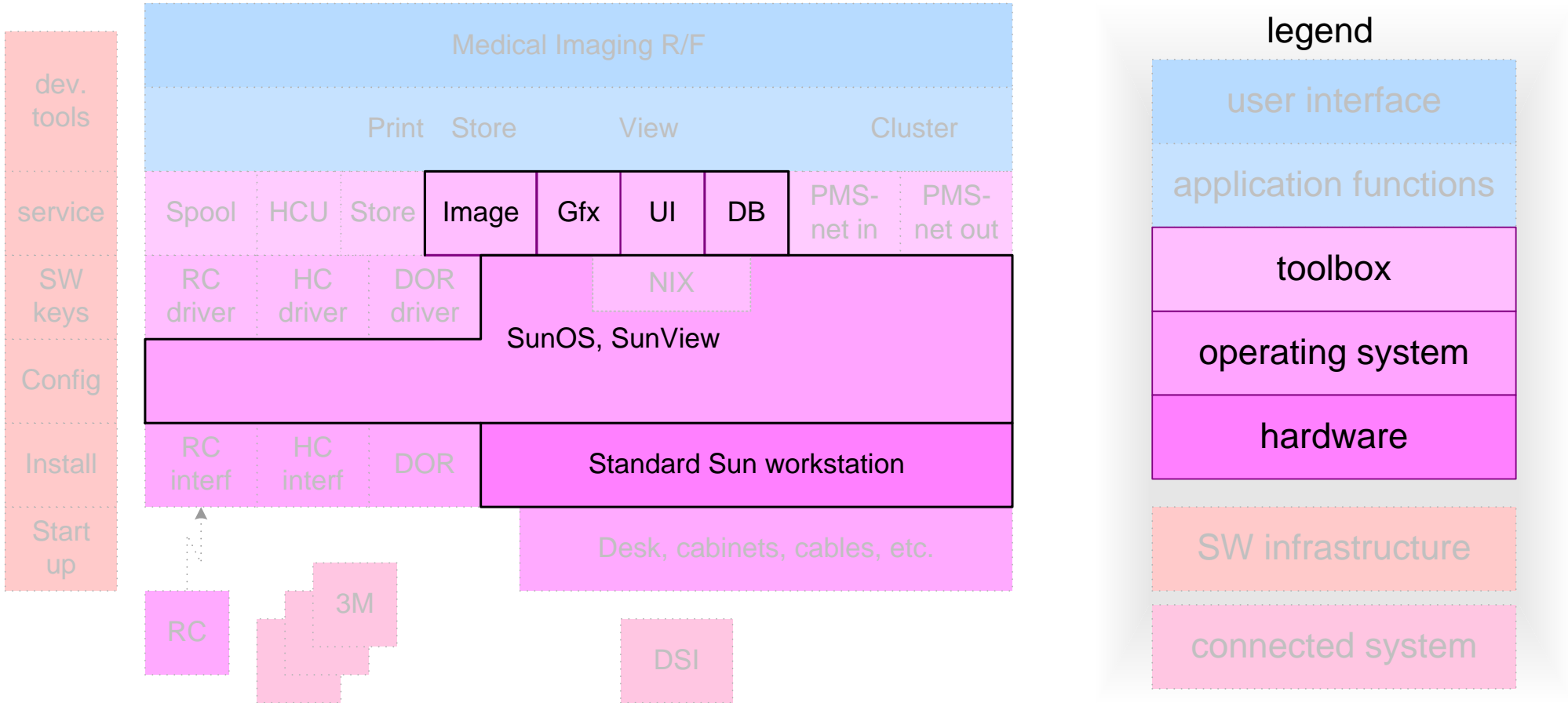
marketing opinion:

"All the functionality is available,
we only have to provide a clinical UI"

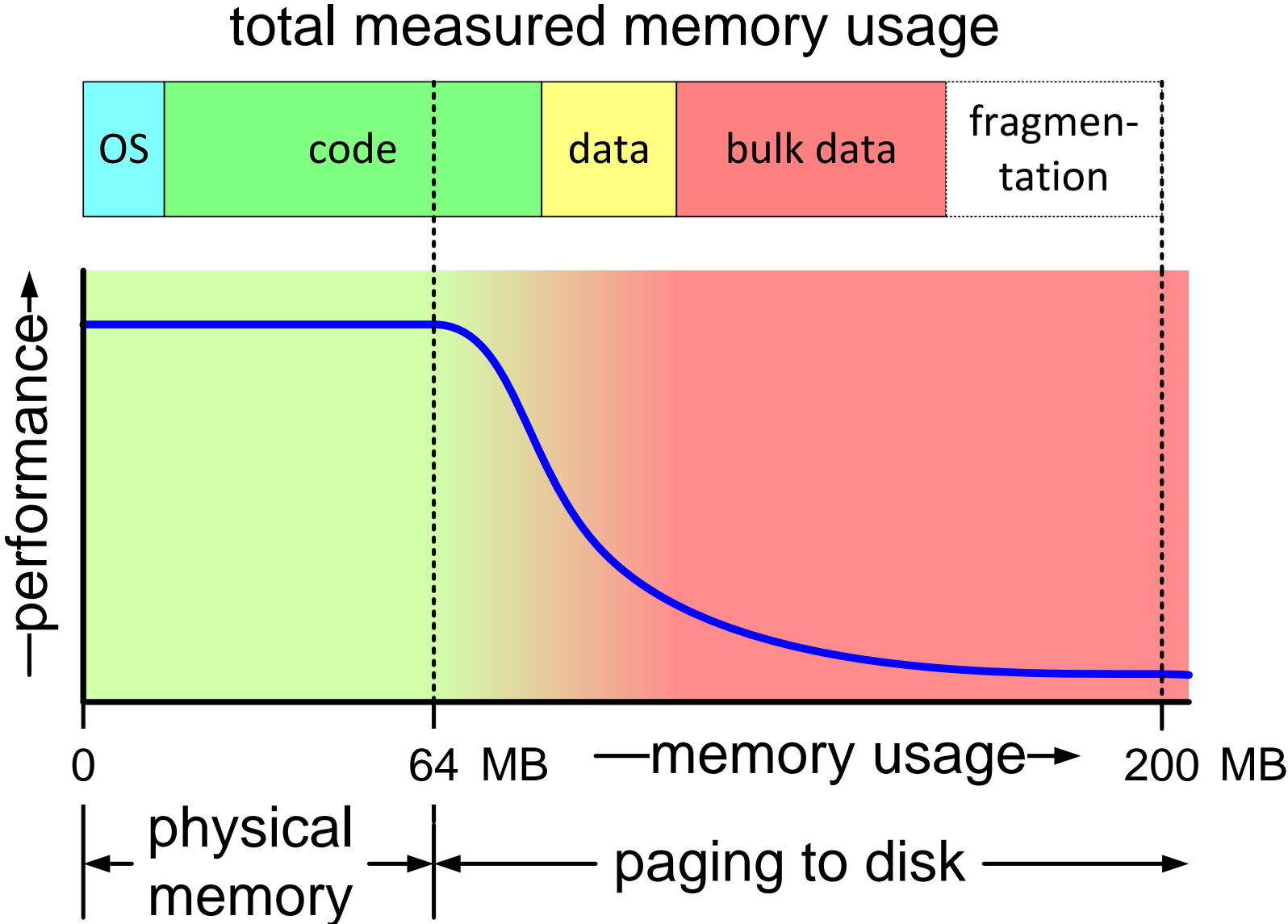
SW Process structure 1991



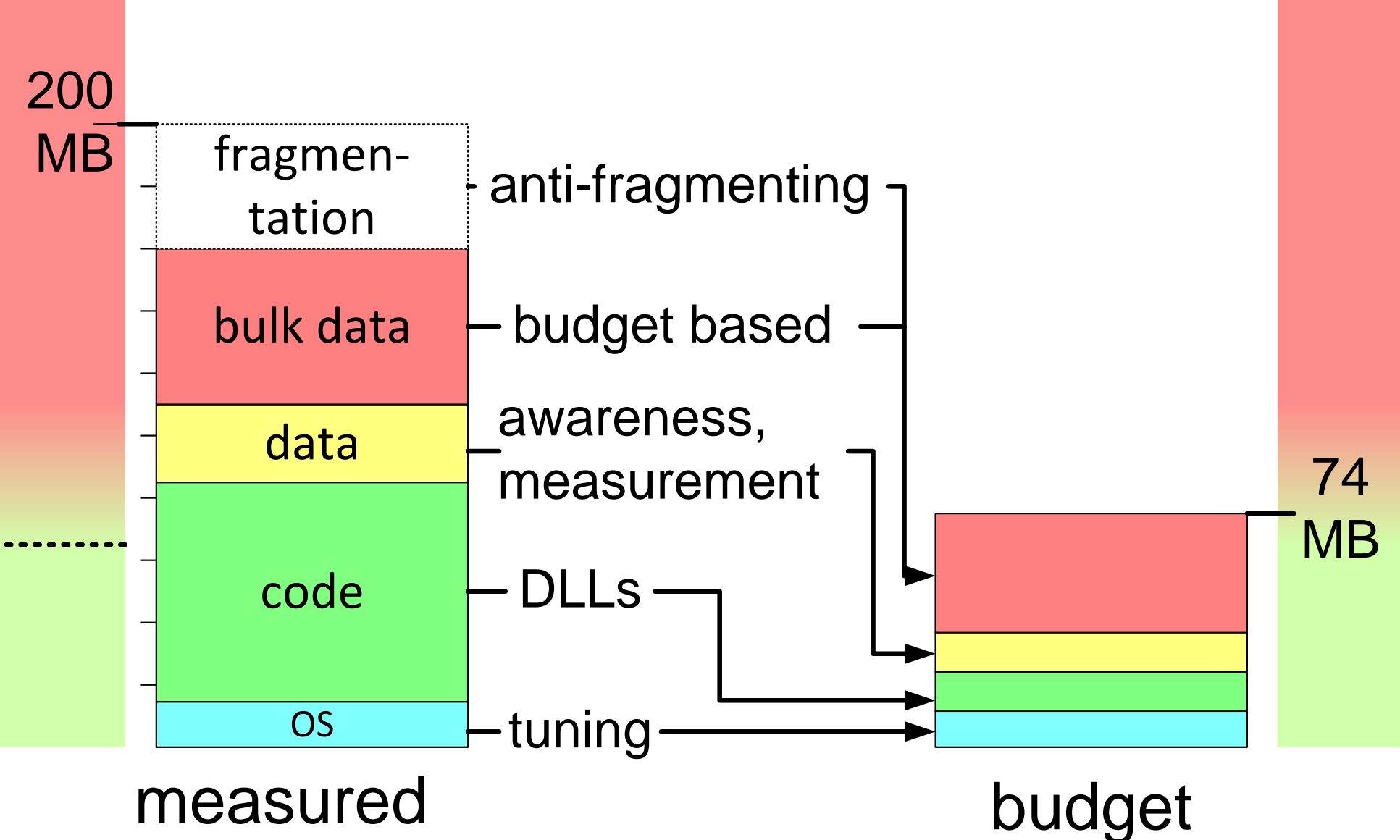
SW layers 1991



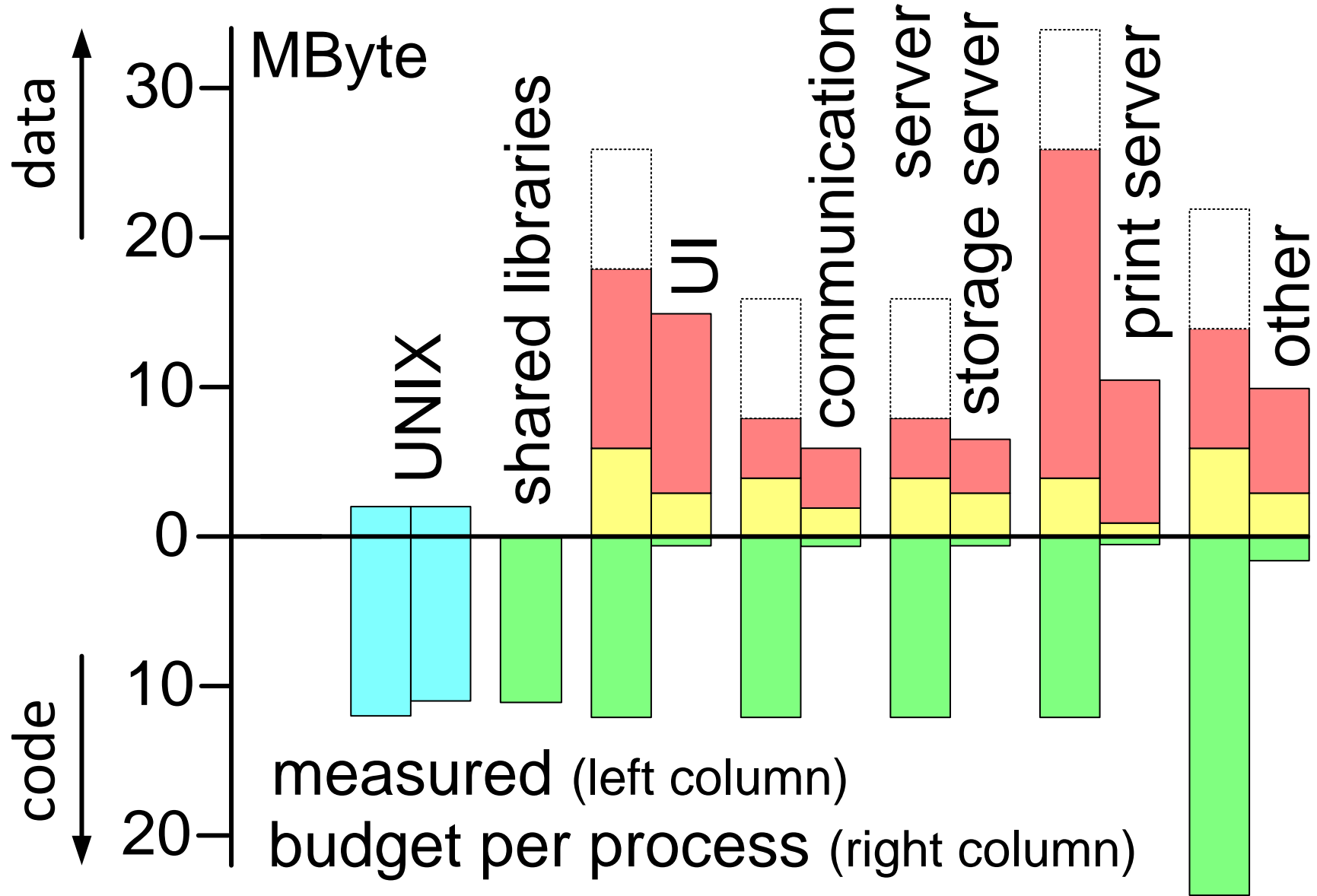
Memory usage half way R1



Solution of memory performance problem



Visualization memory use per process



Causes of performance problems other than memory use

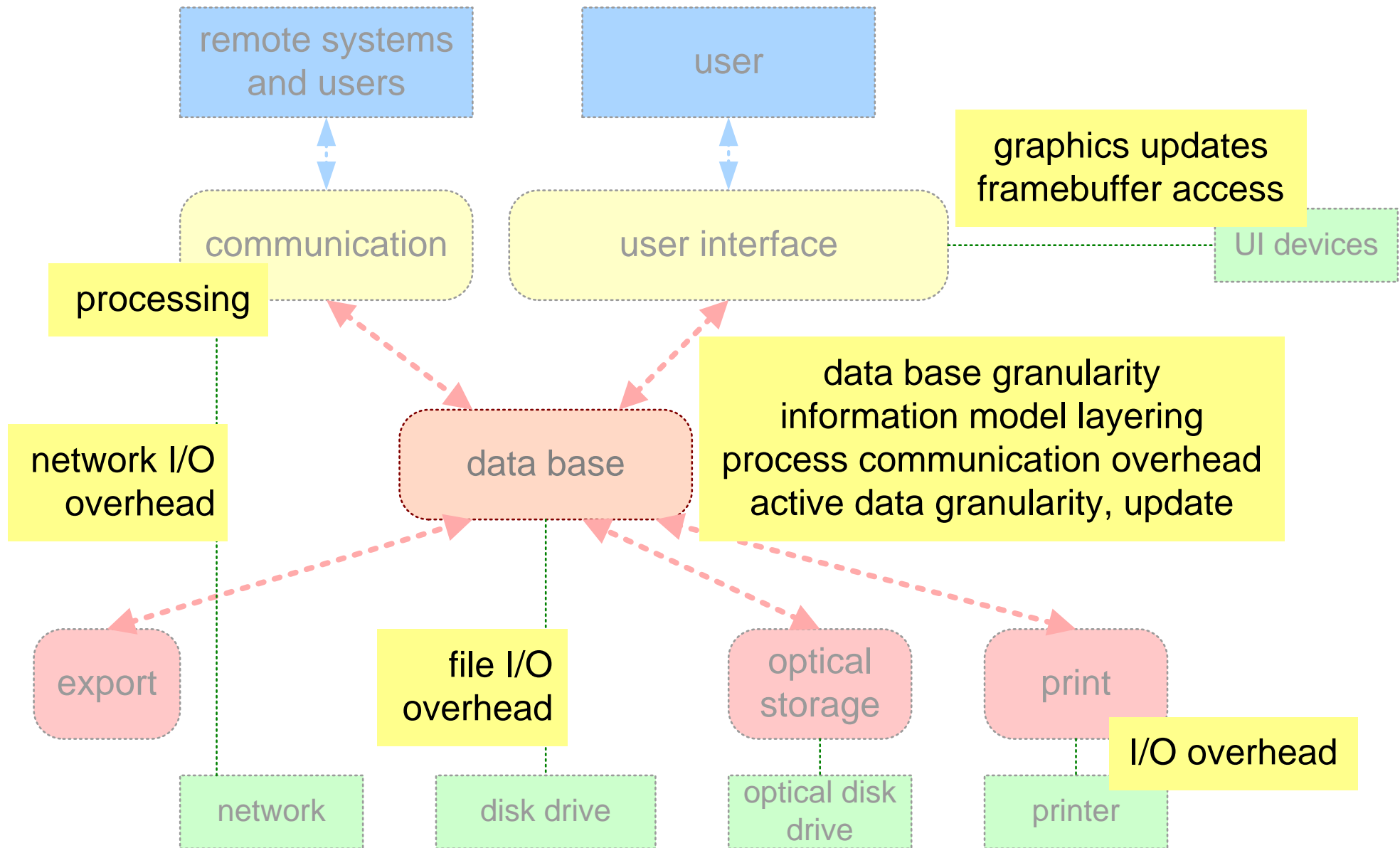
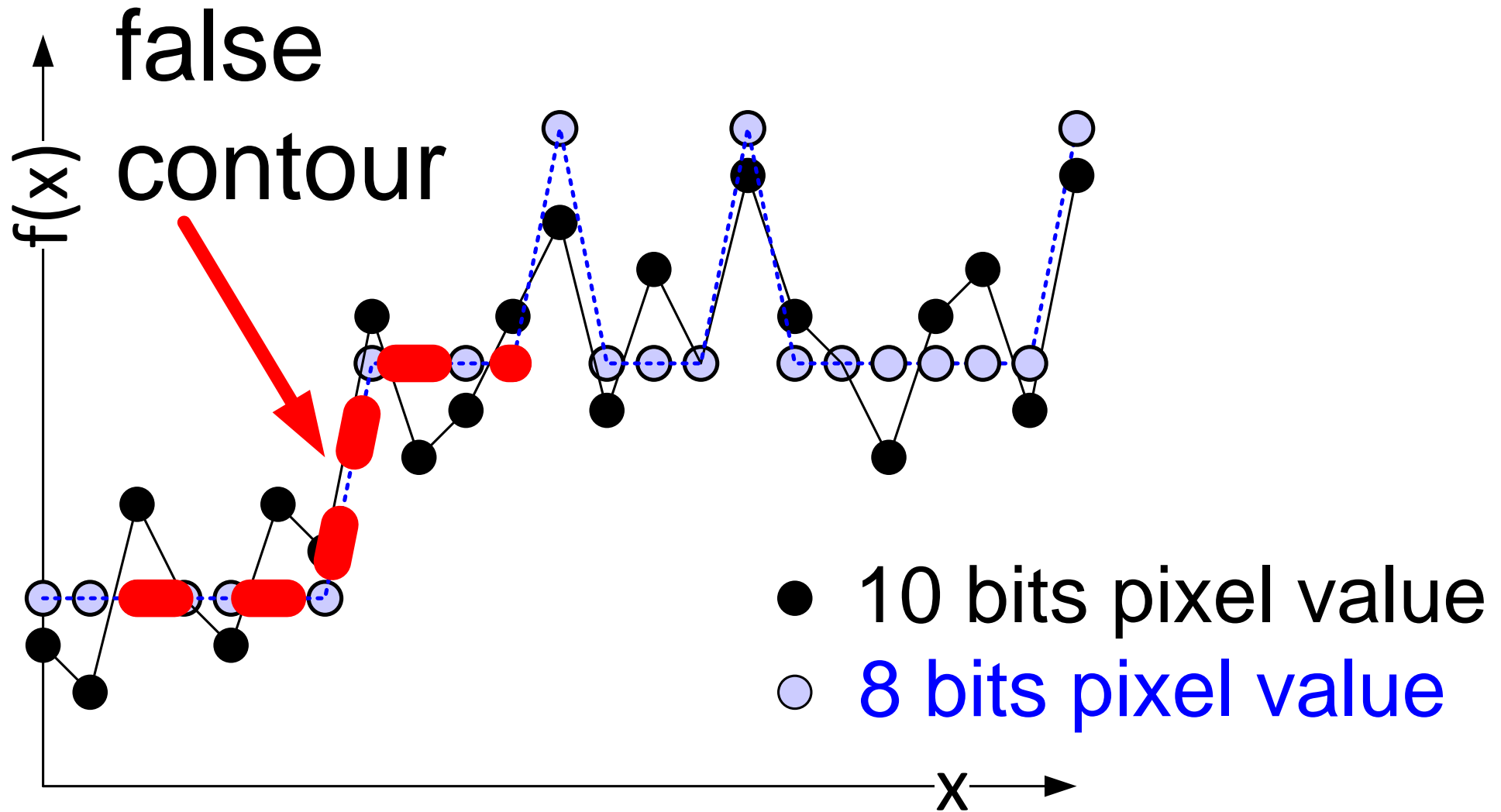
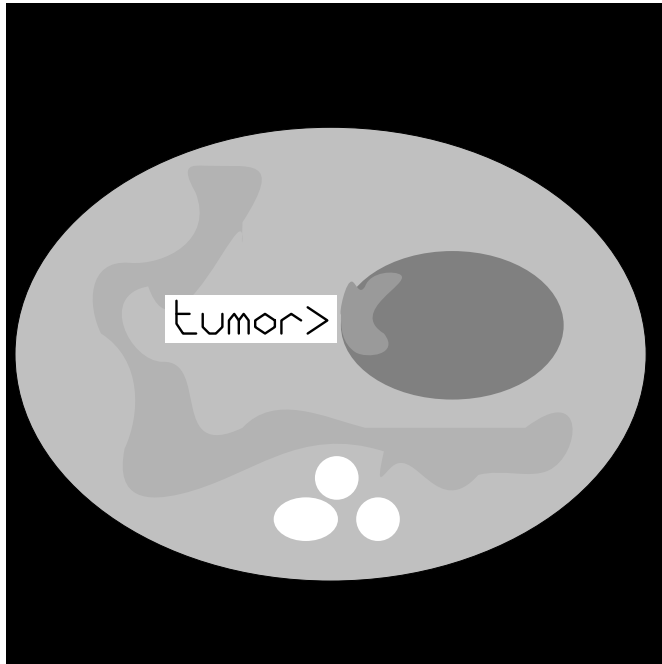


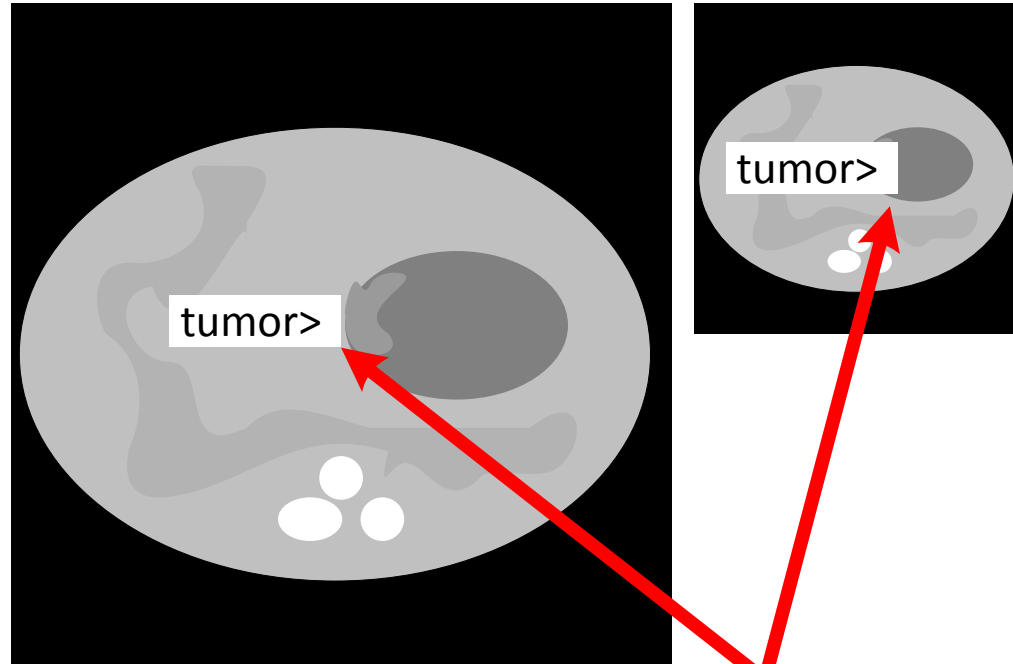
Image quality and safety problem



Safety problem



URF monitor output:
fixed size letters at fixed grid



for user readability the font-size was determined "intelligently"; causing a dangerous mismatch between text and image

EV output: scaleable fonts in graphics overlay

Medical Imaging Workstation: CAF Views

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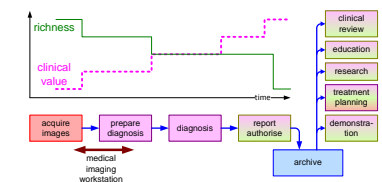
Abstract

The Customer objectives, Application and Functional views are described. The radiology department and the radiologist are the main customer. The clinical and the financial context of the radiology department is shown. The medical imaging workstation is positioned in the field of IT products and in the clinical workflow. The market segmentation is shown. The typical URF examination is explained. Key drivers are linked to application drivers and to product requirements. The functionality development over time is shown and the role of the information model for interoperability is discussed.

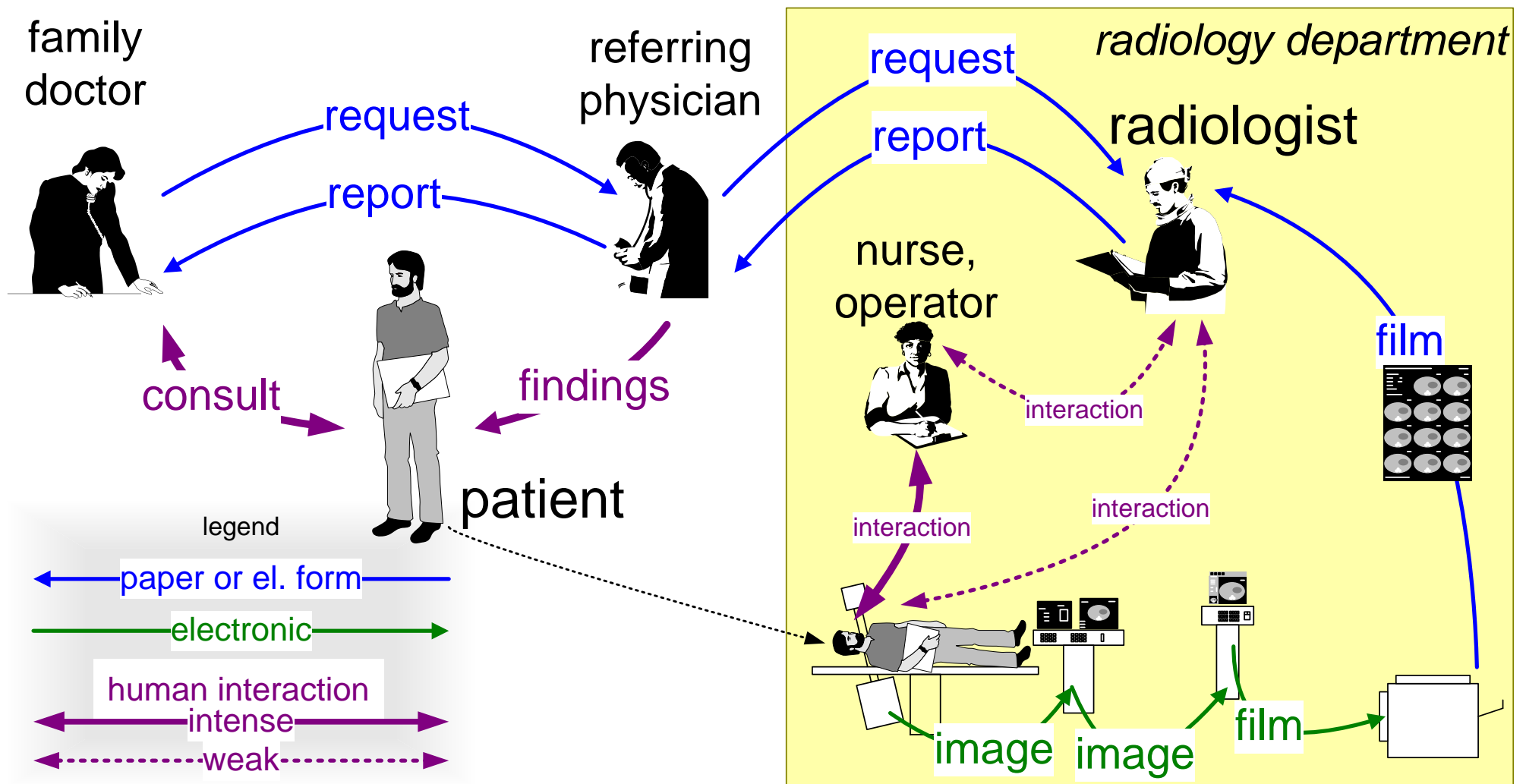
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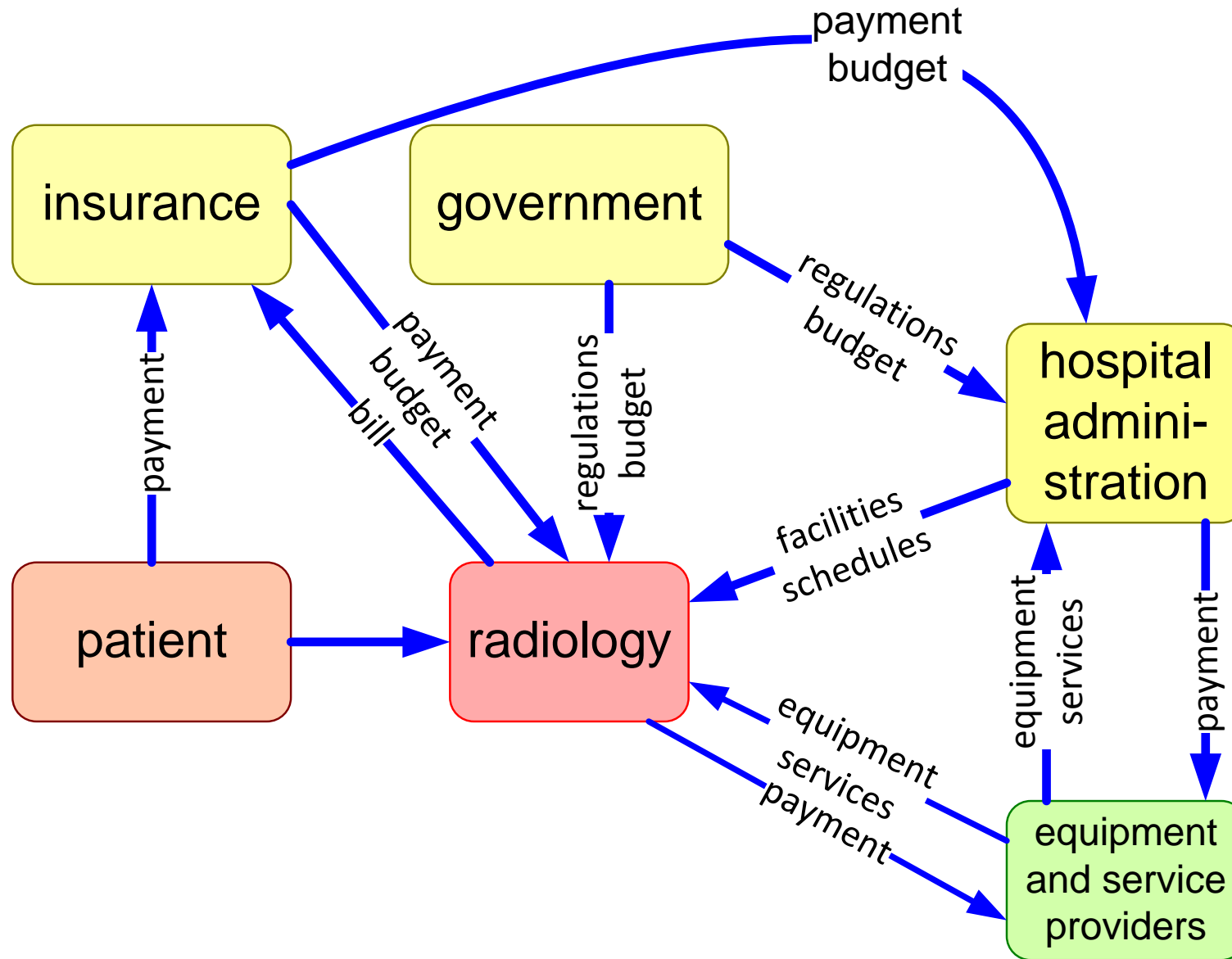
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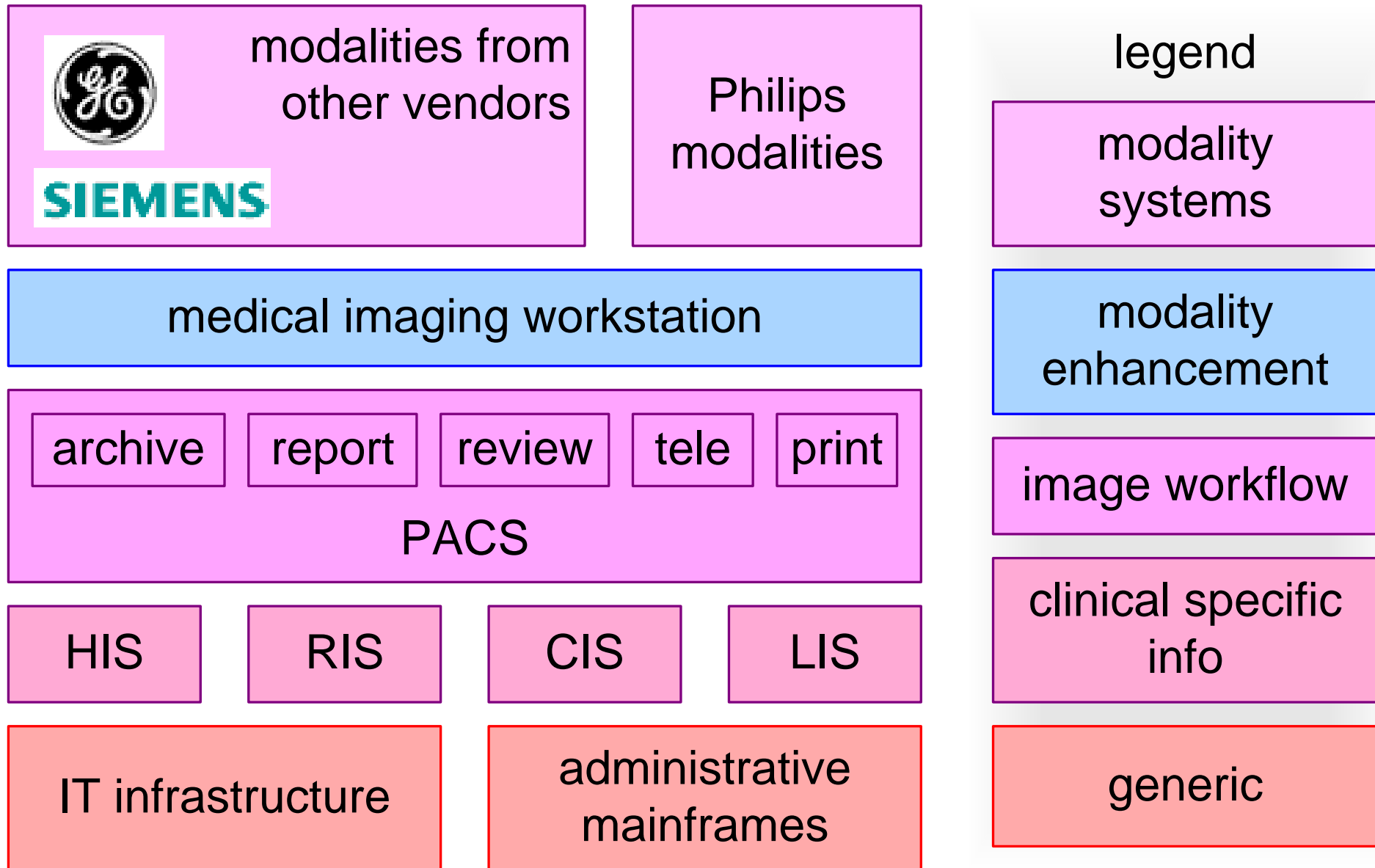
The clinical context of the radiology department



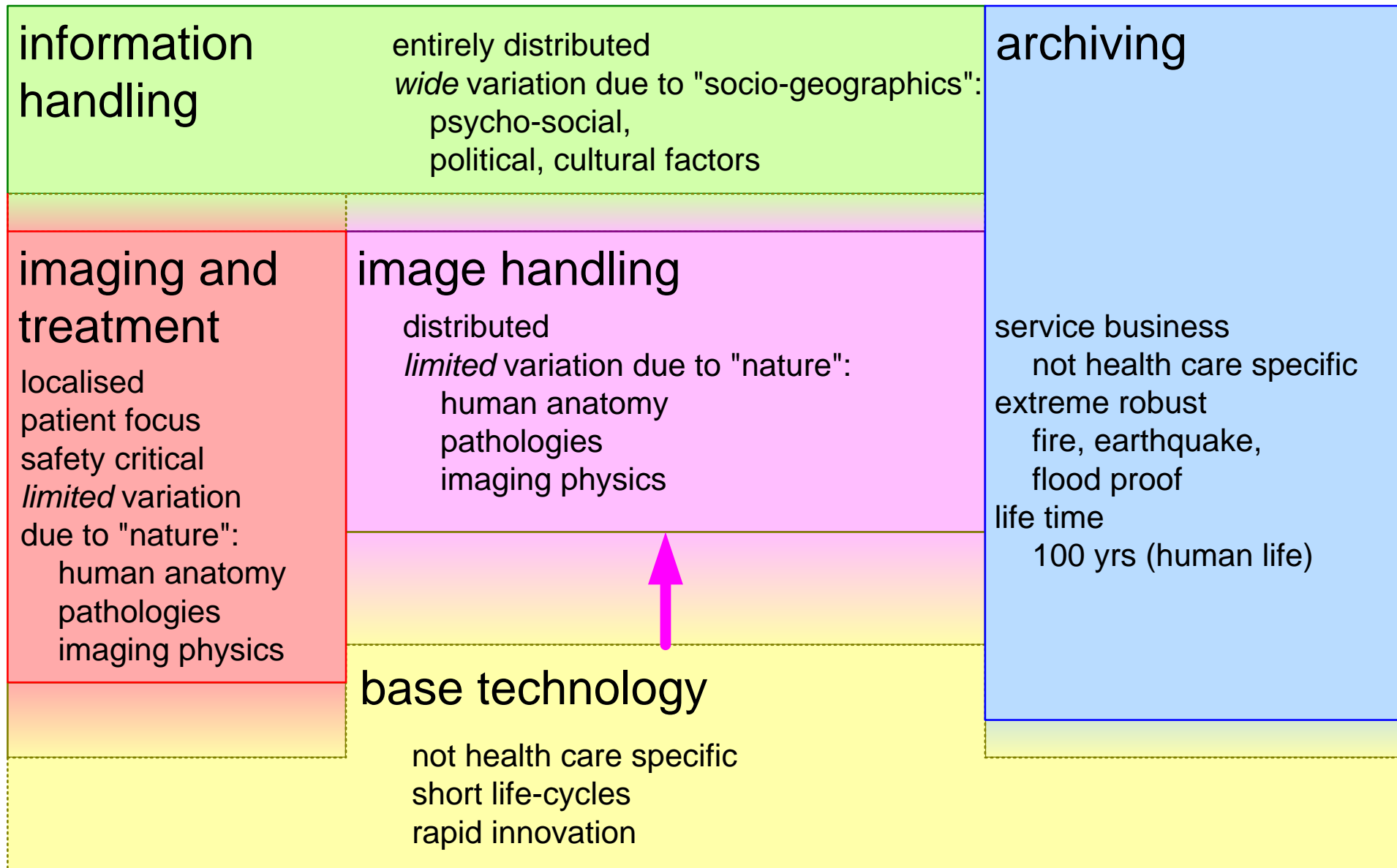
The financial context of the radiology department



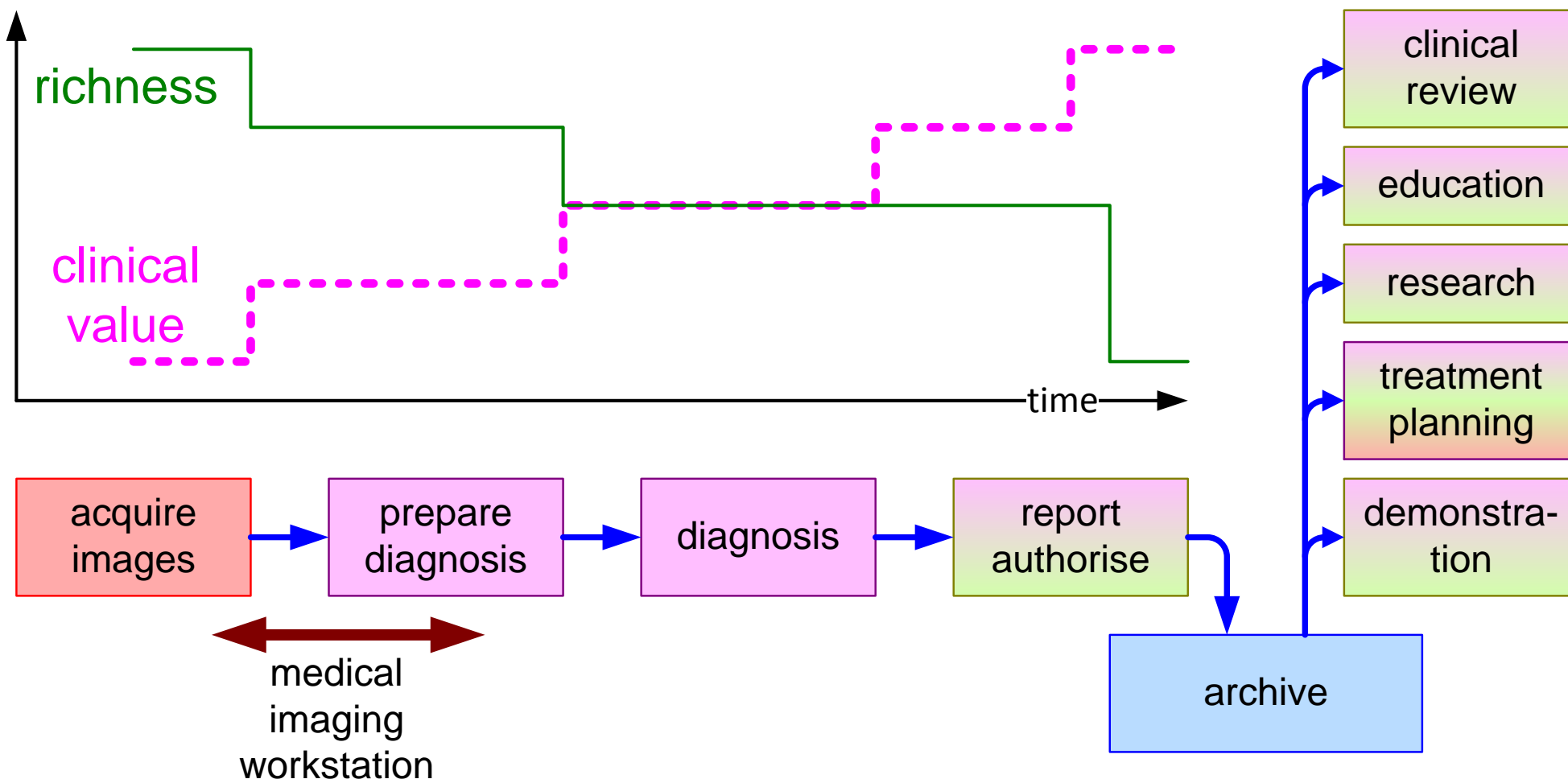
Application layering of IT systems



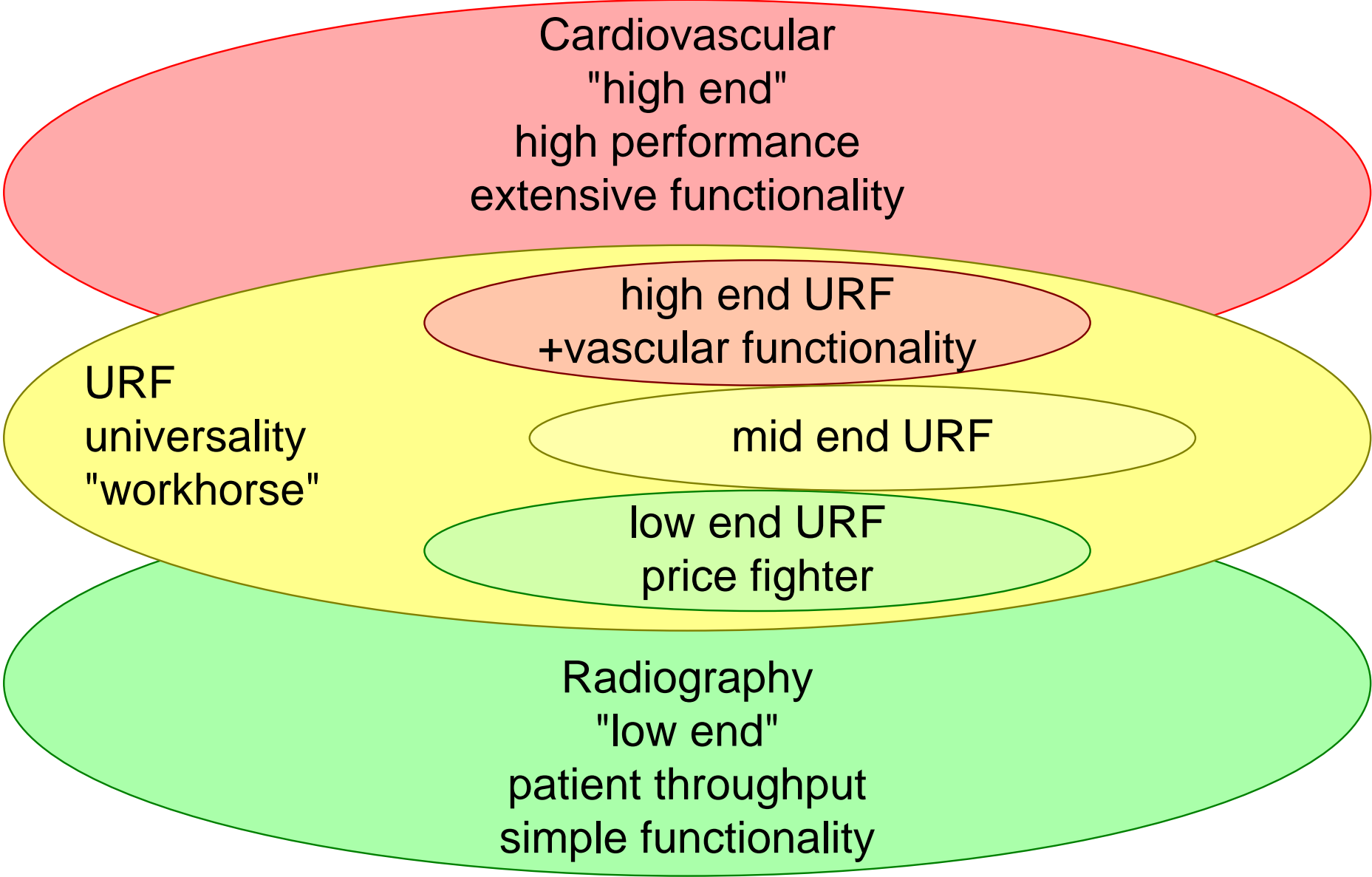
Reference model for healthcare automation



Clinical information flow



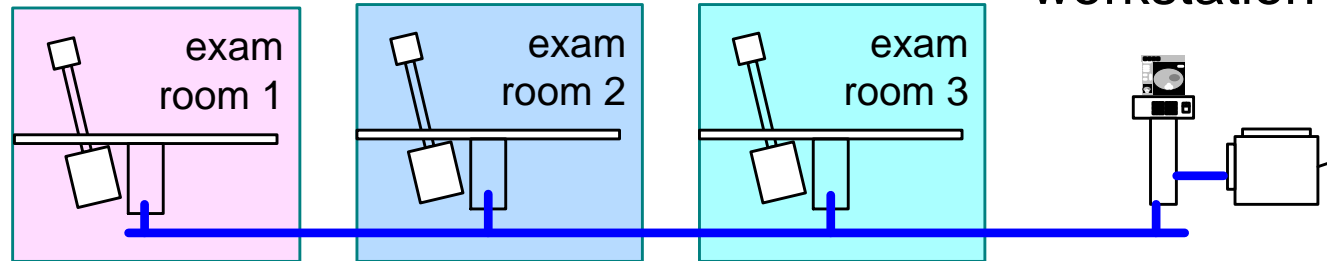
URF market segmentation



Typical case URF examination

3 examination rooms connected to

1 medical imaging workstation + printer

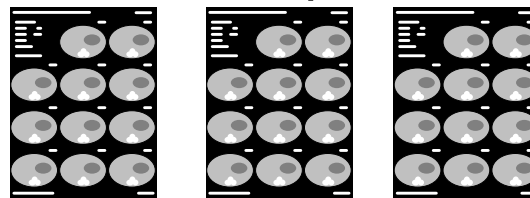


examination room: average 4 interleaved examinations / hour

image production: 20 1024^2 8 bit images per examination

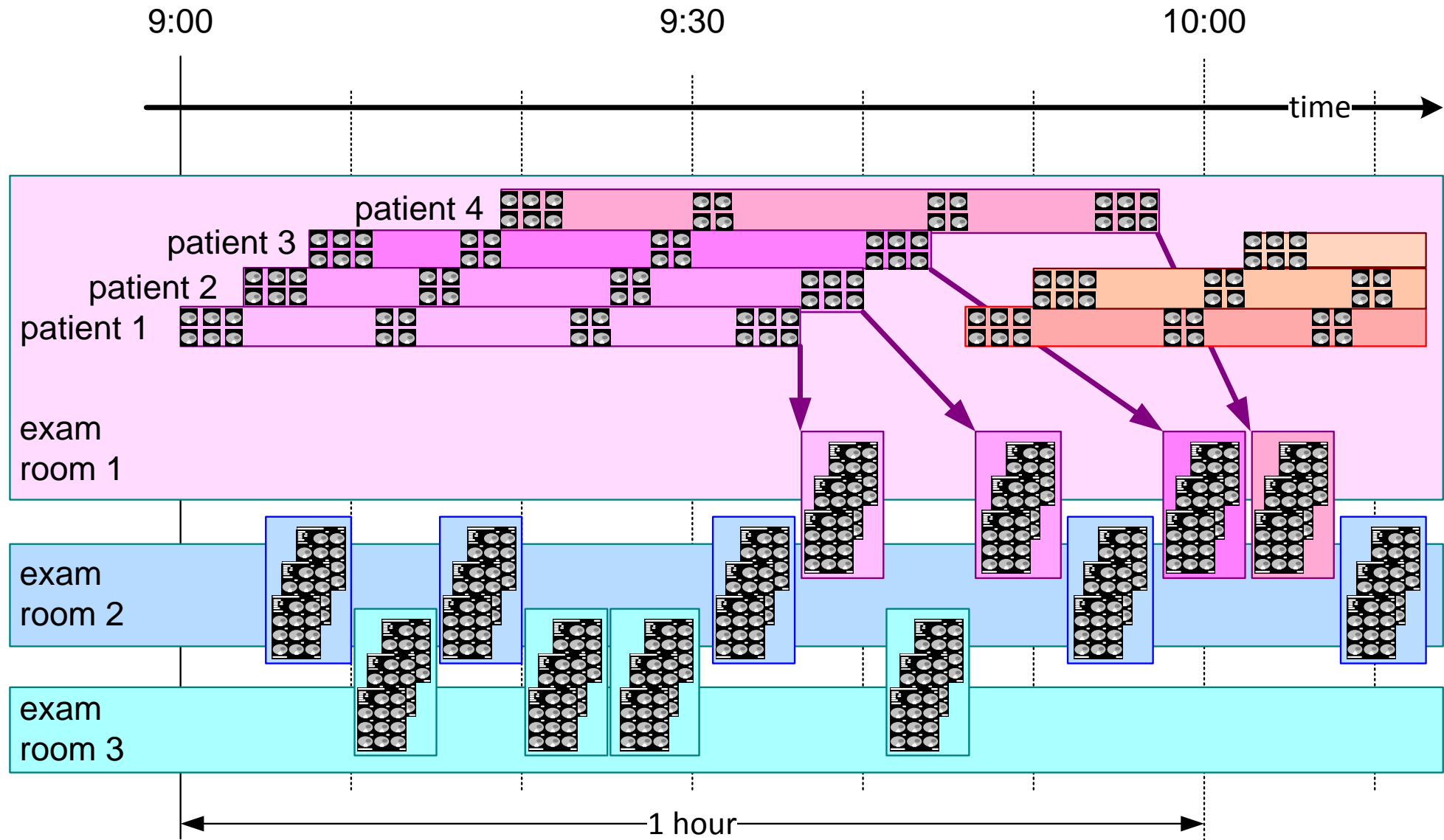


film production: 3 films of 4k*5k pixels each



high quality output
(bi-cubic interpolation)

Timing of typical URF examination rooms



Key drivers, application drivers and requirements

Customer key drivers

derived Application drivers

report quality

selection of relevant material
use of standards

diagnostic quality

acquisition and viewing settings
contrast, brightness and resolution of light-box

safety and liability

clear patient identification
left right indicators
follow procedures
freeze diagnostic information

cost per diagnose

interoperability over systems and vendors
multiple images per film
minimise operator handling
multiple applications per system

time per diagnose

diagnose at light-box with films
all preparation in exam room

Requirements

import

auto-print

parameterized layout
spooling

storage

navigation / selection
auto-delete

viewing

contrast / brightness
zoom

annotate

export

functionality

system response

system throughput

image quality

annotation

material cost

operational cost

qualities

shared information model

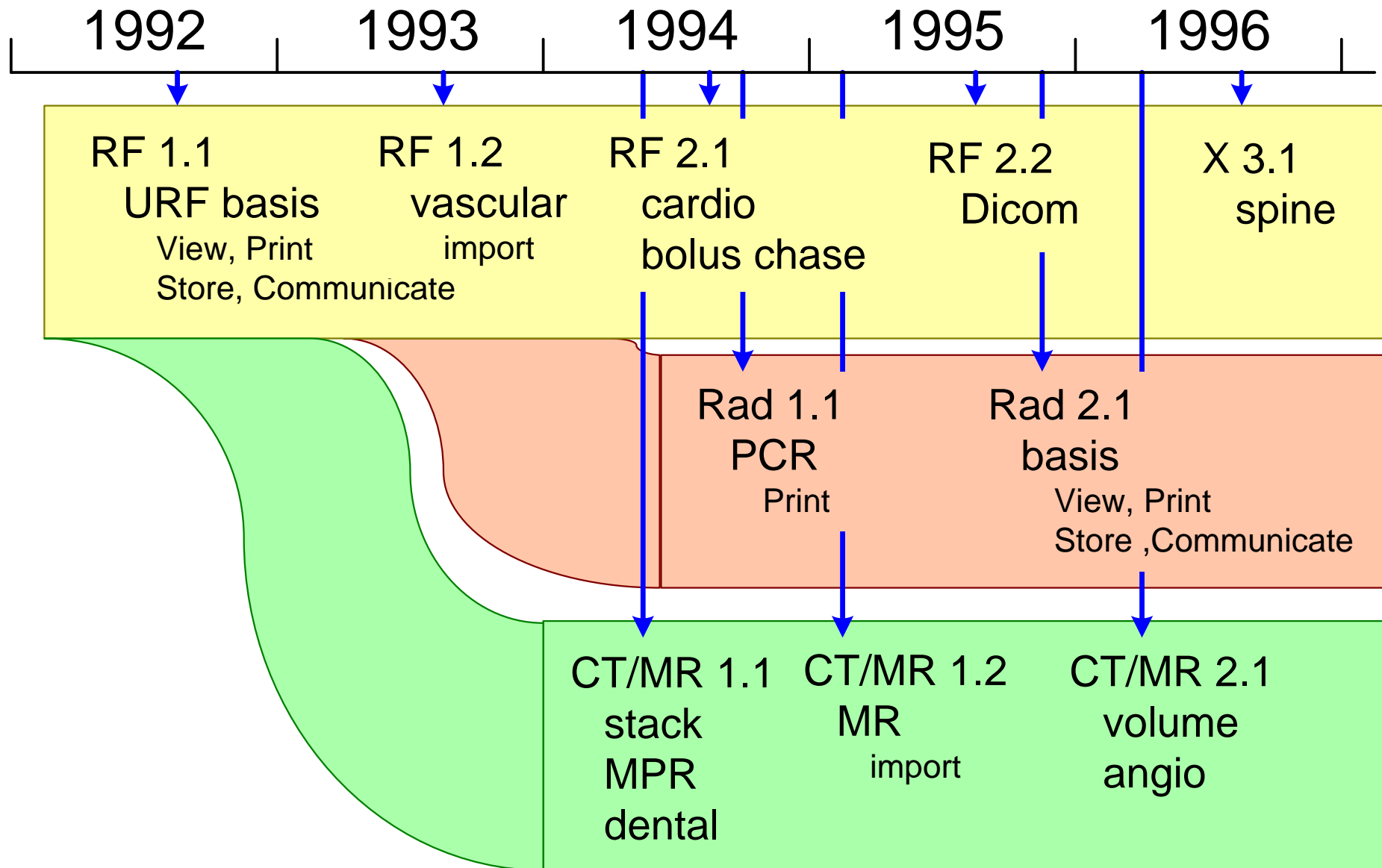
viewing settings

patient, exam info

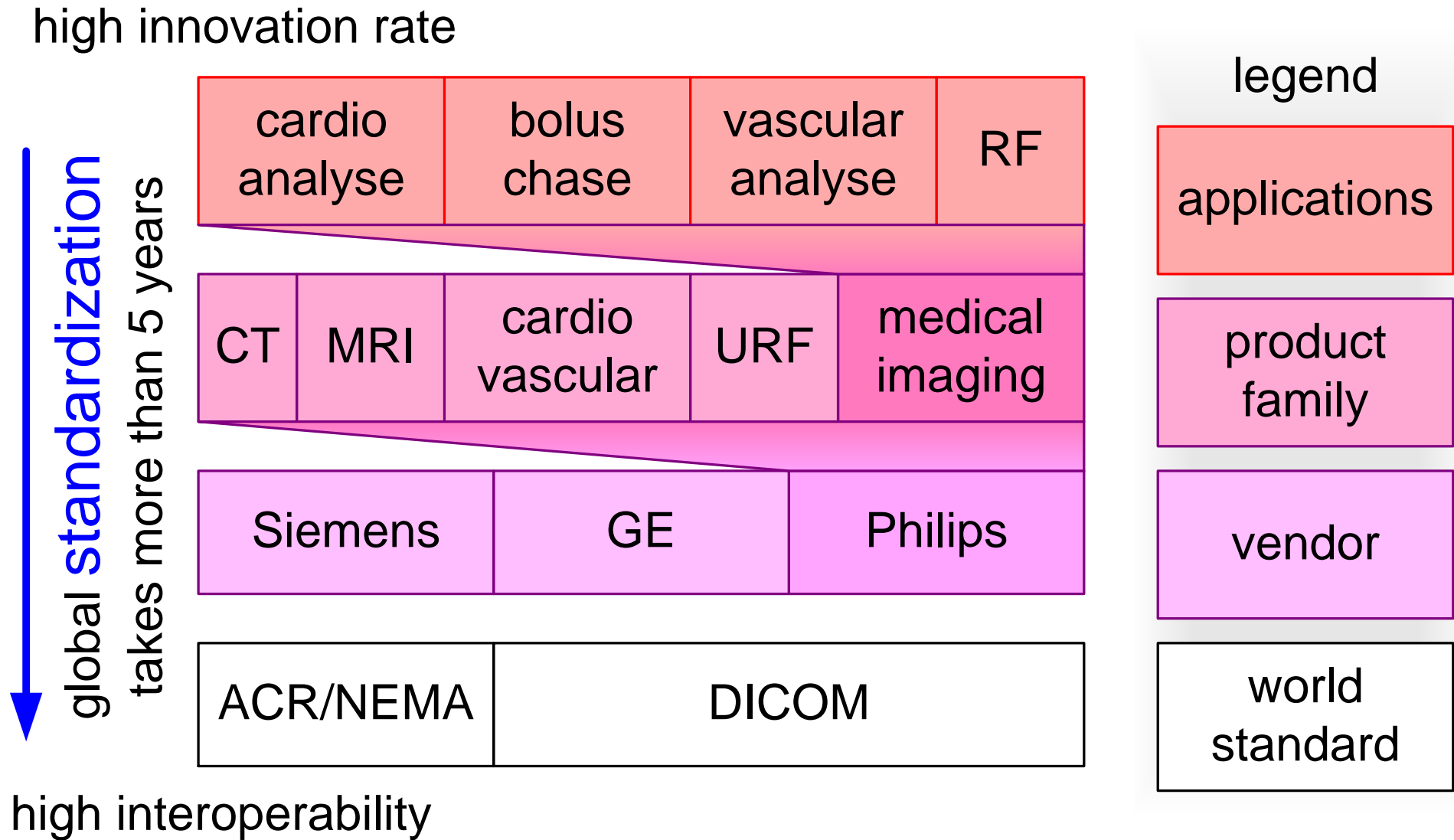
interfaces

many
to
many

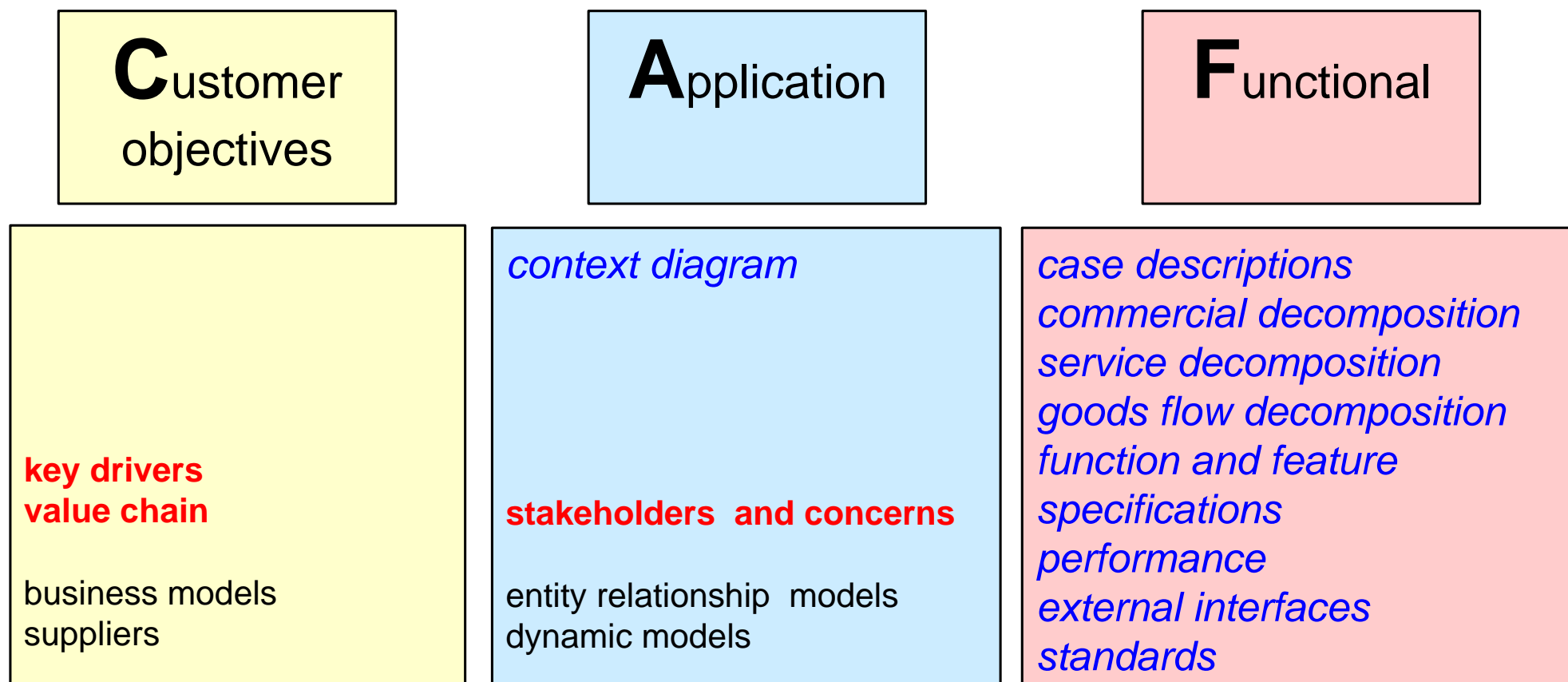
Retrospective functionality roadmap



Information model, standardization for interoperability



Coverage of submethods of the CAF views



legend

explicitly addressed

addressed only implicitly

not addressed

coverage based on documentation status of first product release

Medical Imaging Workstation: CR Views

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Abstract

The concepts and realization of the medical imaging workstation are described. The following concepts are described: presentation and processing pipeline, resource management (CPU and memory), including caching and anti-fragmentation strategy, software process decomposition and decomposition rules. The actual realization figures serve as illustration for the justification of some of the concepts.

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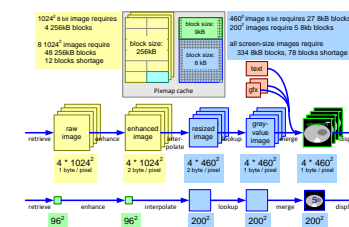
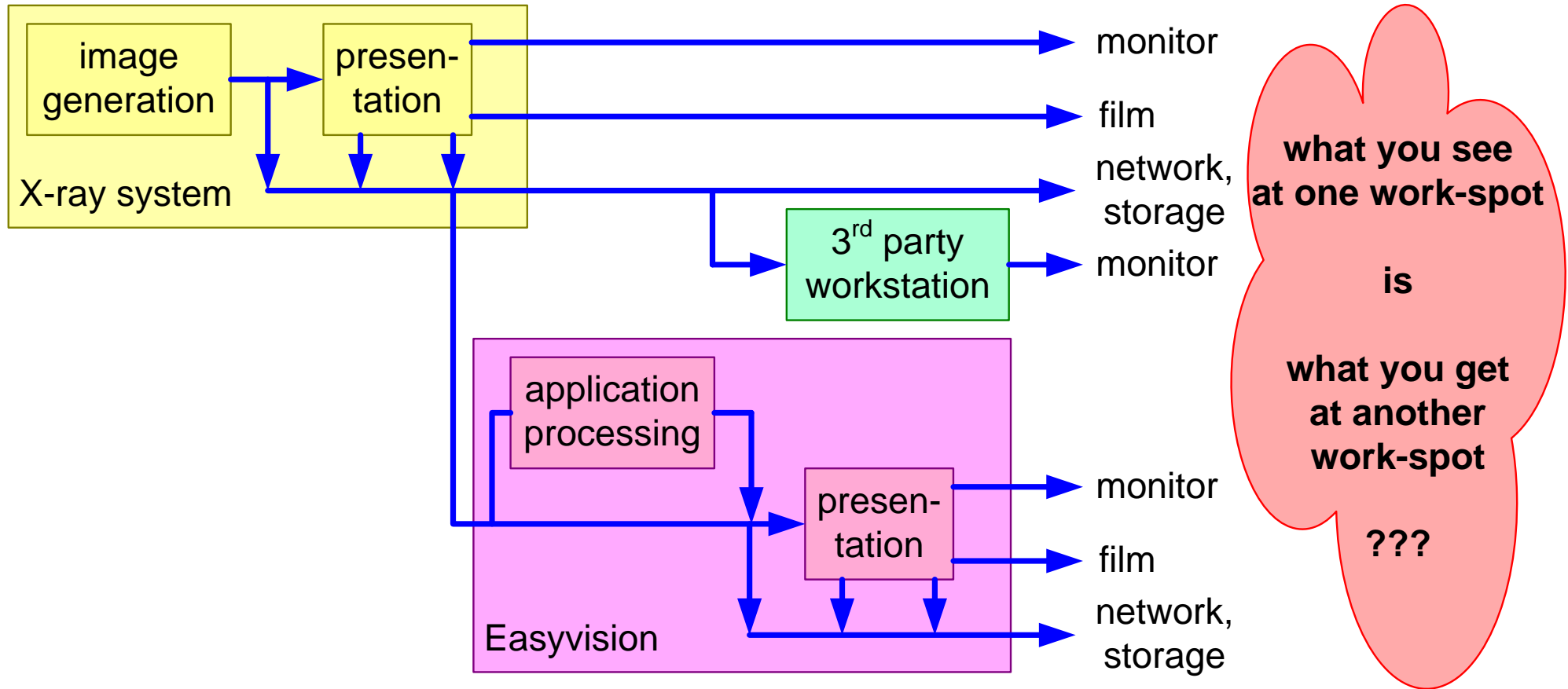
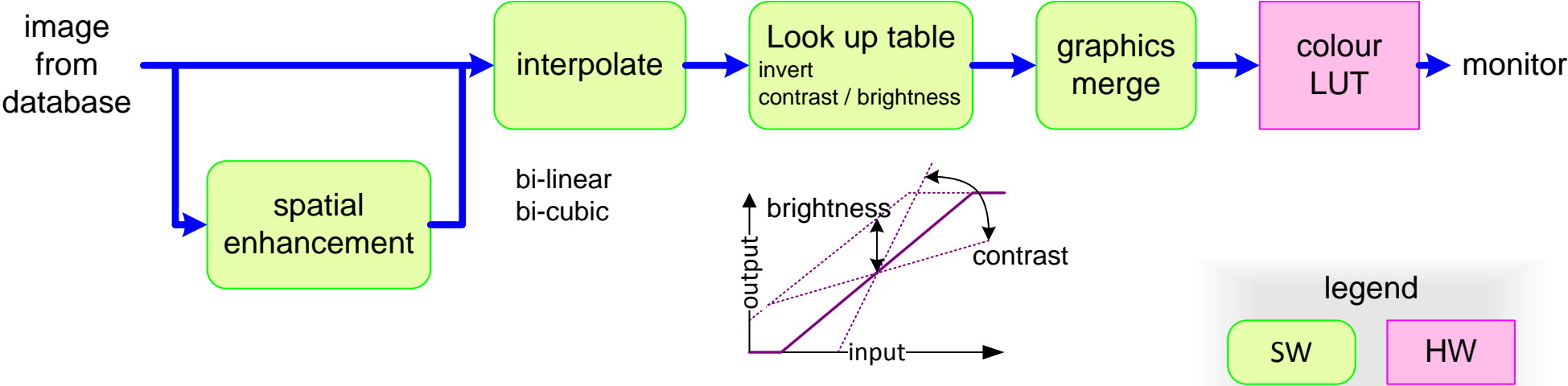


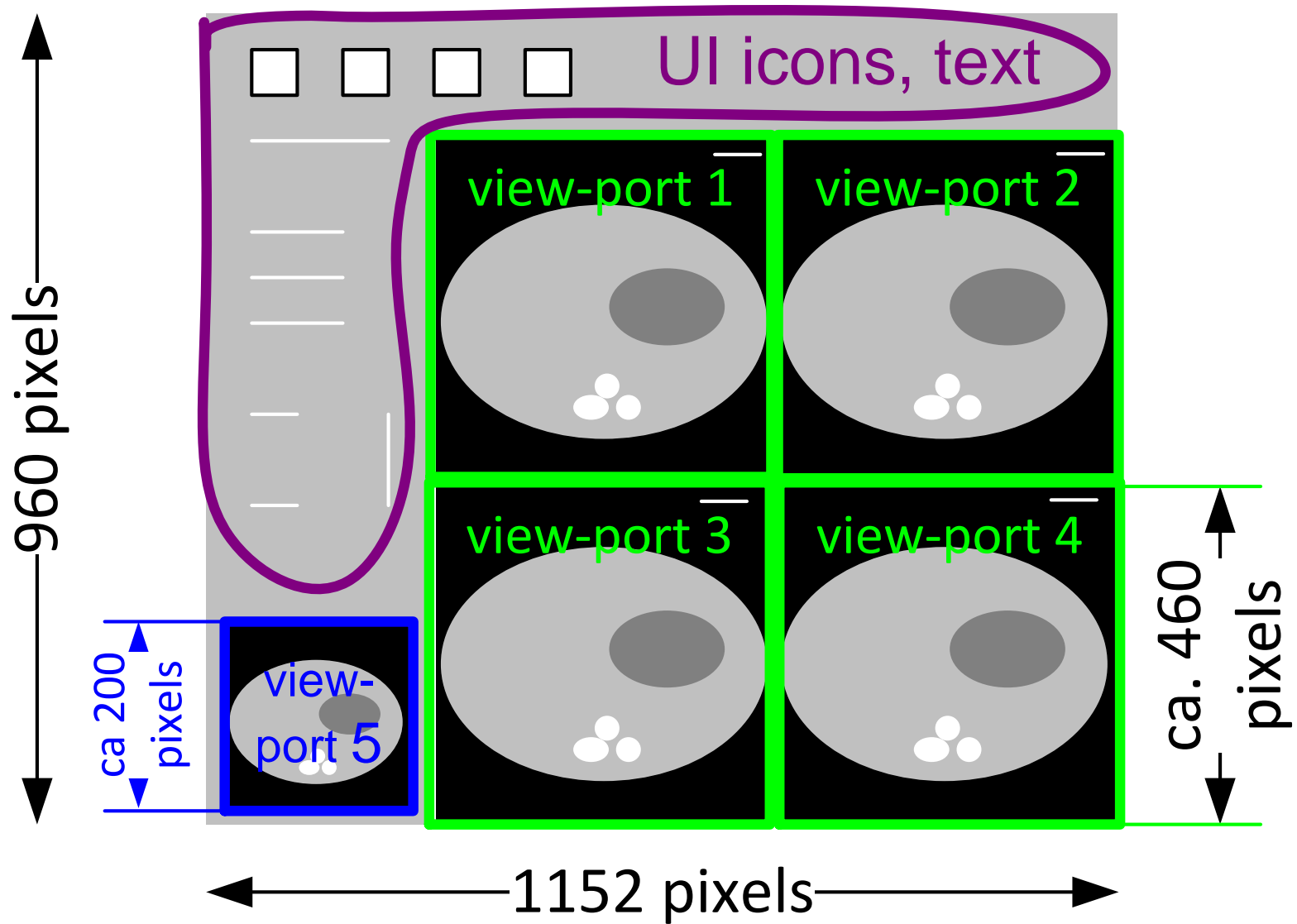
Image Quality expectation WYSIWYG



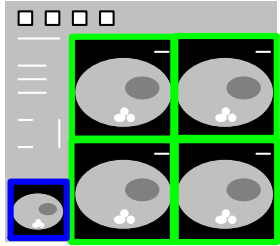
Presentation pipeline for X-ray images



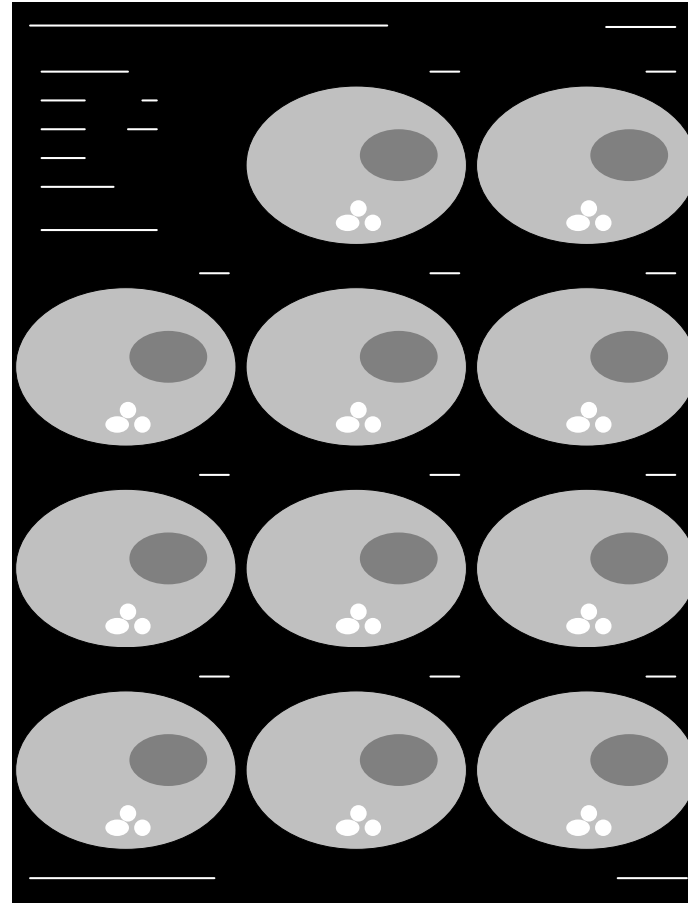
Quadruple view-port screen layout



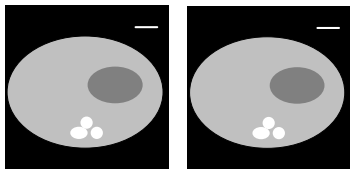
Rendered images at different destinations



Screen:
low resolution
fast response

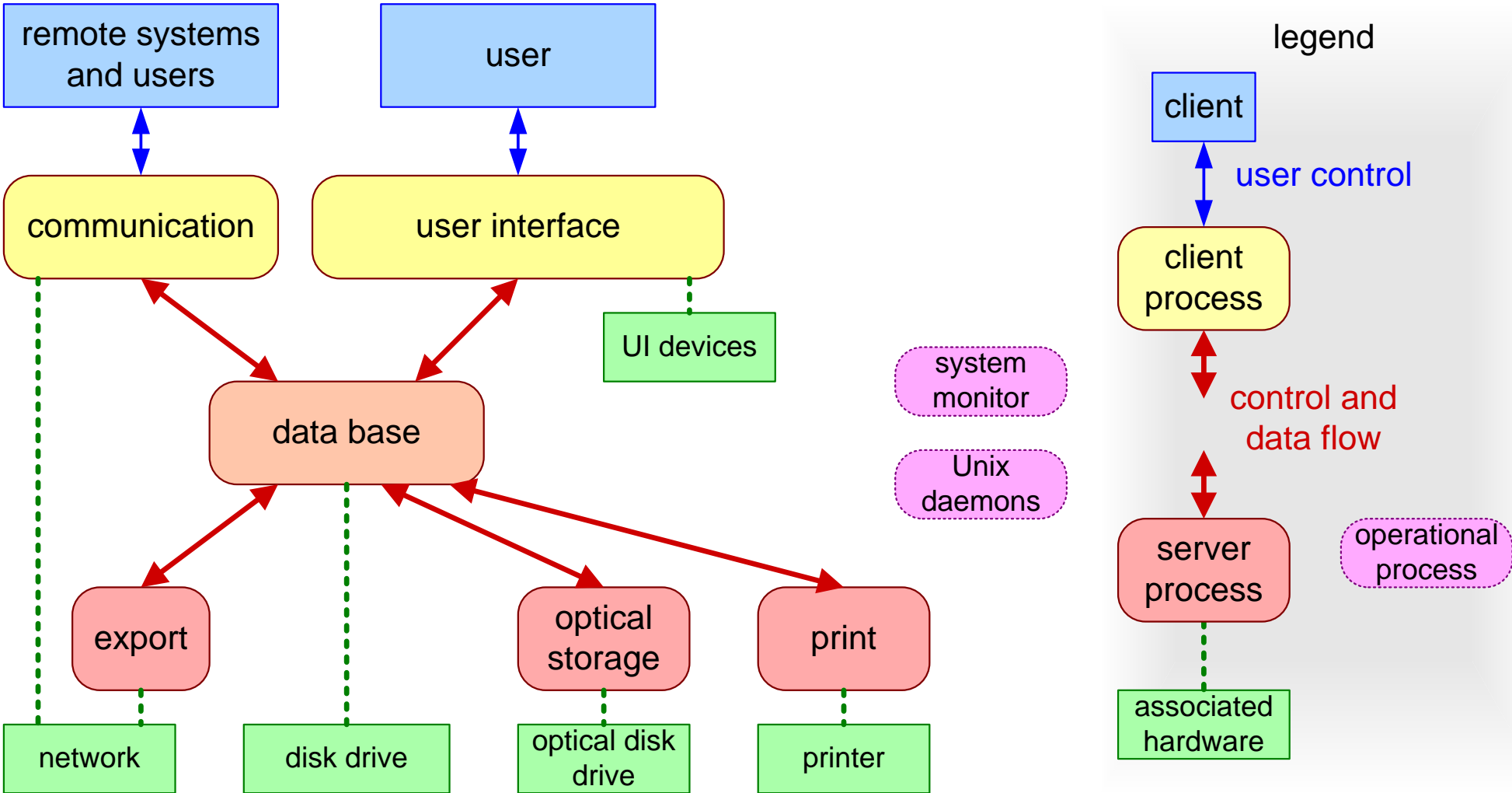


Film:
high resolution
high throughput



Network:
medium resolution
high throughput

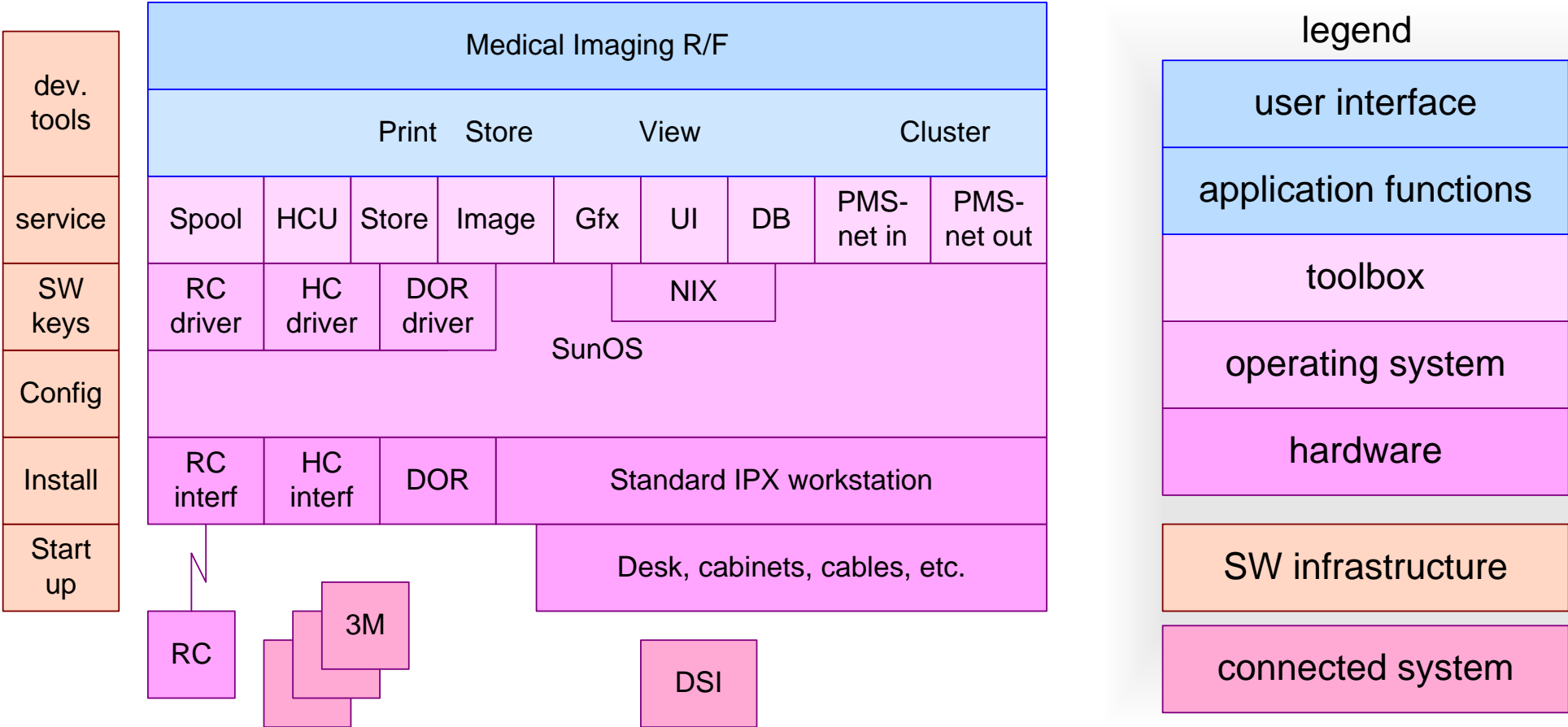
Concurrency via software processes



Criteria for process decomposition

- management of concurrency
- management of shared devices
- unit of memory budget (easy measurement)
- enables distribution over multiple processors
- unit of exception handling: fault containment and watchdog monitor

Simplified layering of the software



Memory budget of Easyvision RF R1 and R2

	code		object data		bulk data		total	
<i>memory budget in Mbytes</i>	R1	R2	R1	R2	R1	R2	R1	R2
shared code	6.0	11.0					6.0	11.0
UI process	0.2	0.3	2.0	3.0	12.0	12.0	14.2	15.3
database server	0.2	0.3	4.2	3.2		3.0	4.4	6.5
print server	0.4	0.3	2.2	1.2	7.0	9.0	9.6	10.5
DOR server	0.4	0.3	4.2	2.0	2.0	1.0	6.6	3.3
communication server	1.2	0.3	15.4	2.0	10.0	4.0	26.6	6.3
UNIX commands	0.2	0.3	0.5	0.2			0.7	0.5
compute server		0.3		0.5		6.0		6.8
system monitor		0.3		0.5				0.8
application total	8.6	13.4	28.5	12.6	31.0	35.0	66.1	61.0
UNIX							7.0	10.0
file cache							3.0	3.0
total							76.1	74.0

Memory fragmentation

image 1, 256 kB | image 2, 256 kB | image 3, 256 kB

1. replace image 3 by image 4



image 1, 256 kB |  | image 3, 256 kB



image 1, 256 kB | 4 |  | image 3, 256 kB

2. add image 5

image 1, 256 kB | 4 |  | image 3, 256 kB | image 5, 256 kB

3. replace image 1 by image 6

 | 4 |  | image 3, 256 kB | image 5, 256 kB

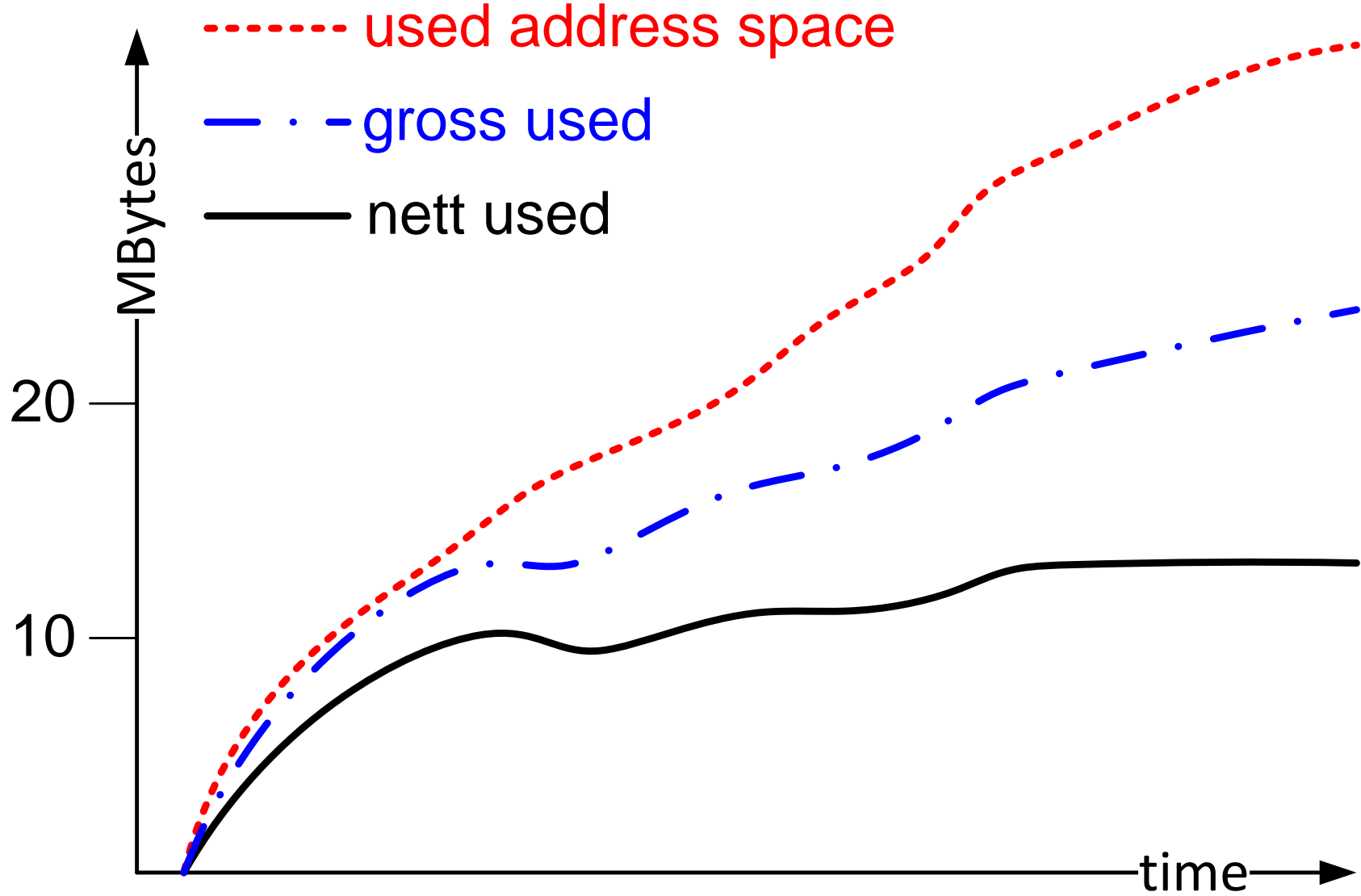
6 |  | 4 |  | image 3, 256 kB | image 5, 256 kB

legend

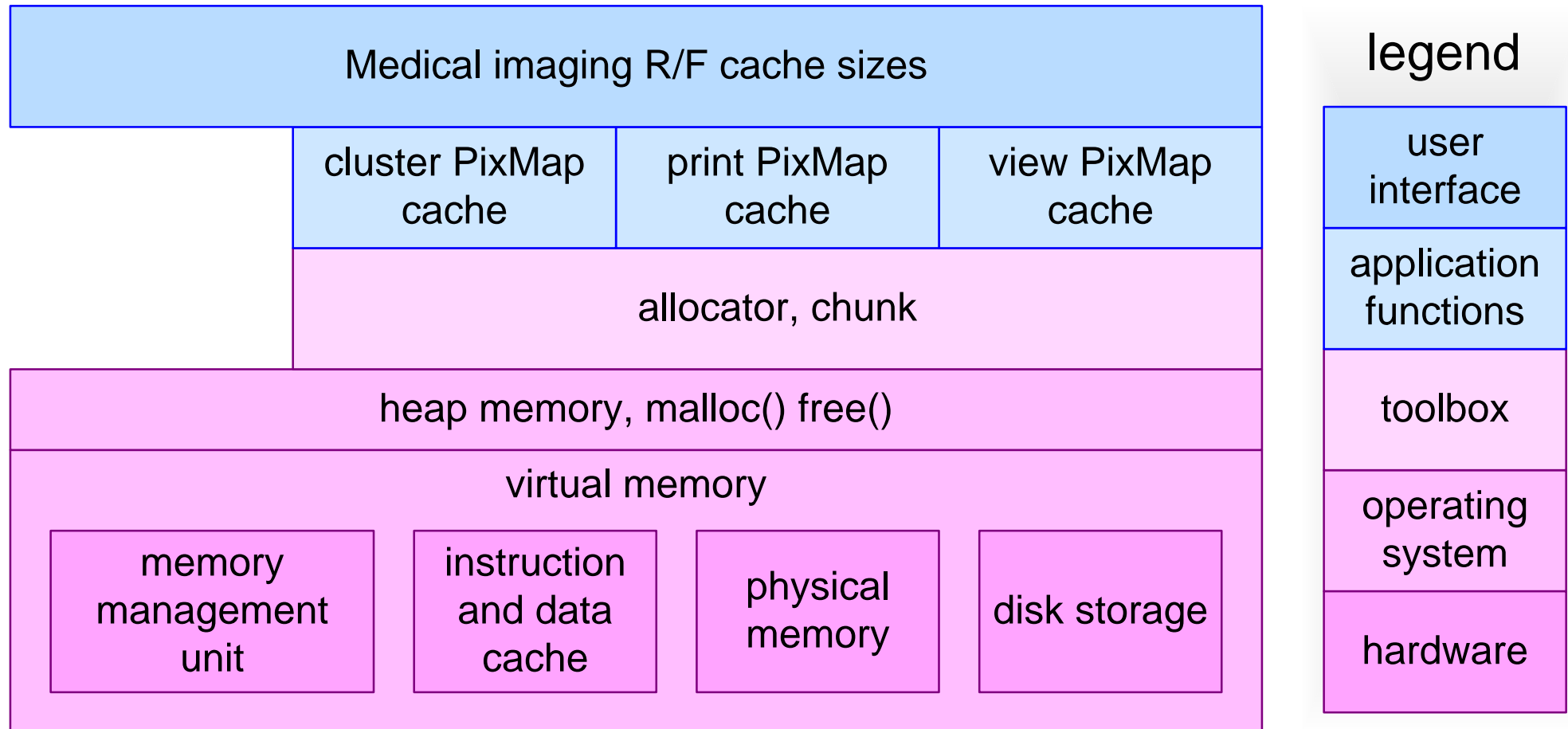
image in use

unused memory

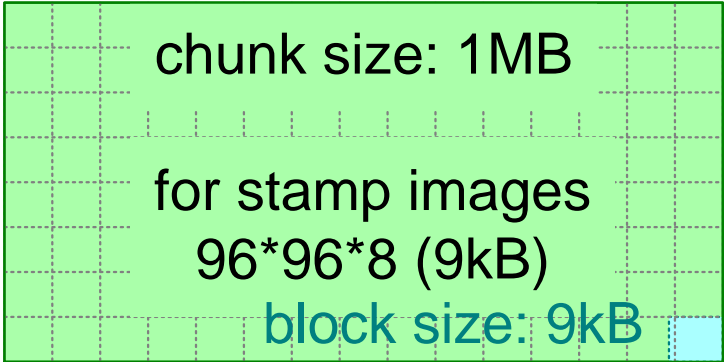
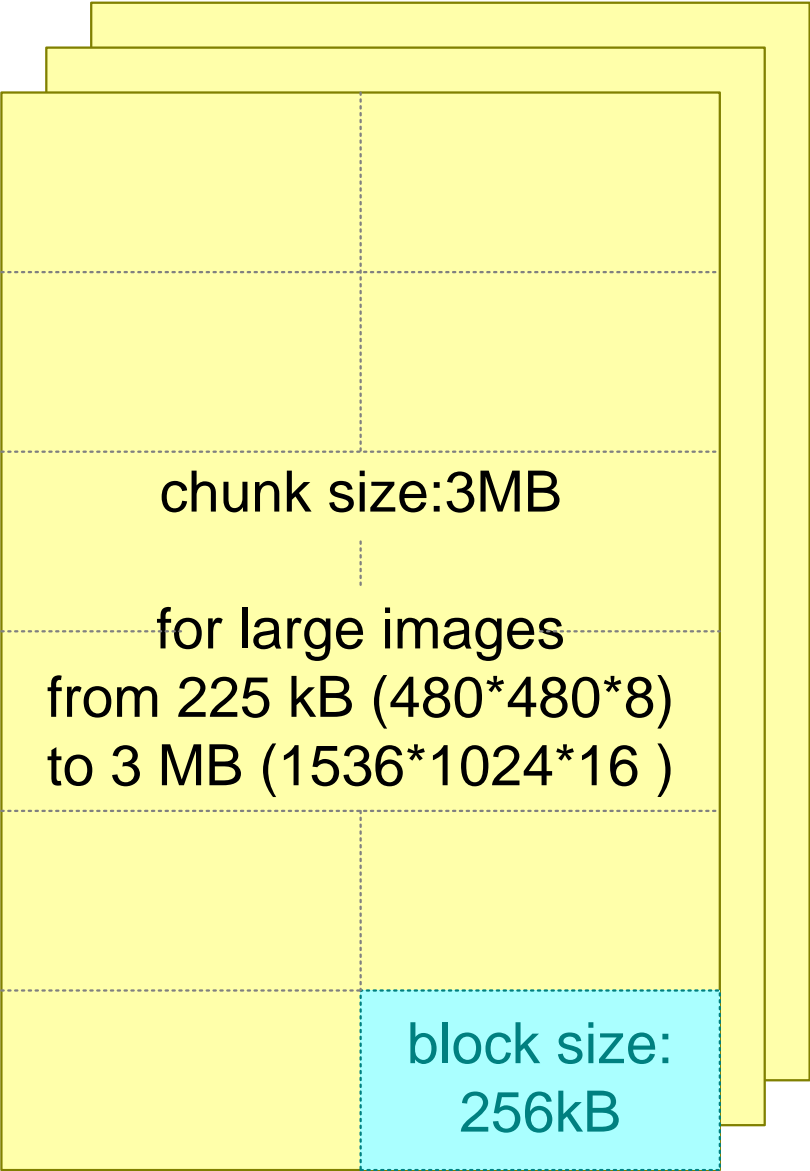
Memory fragmentation increase



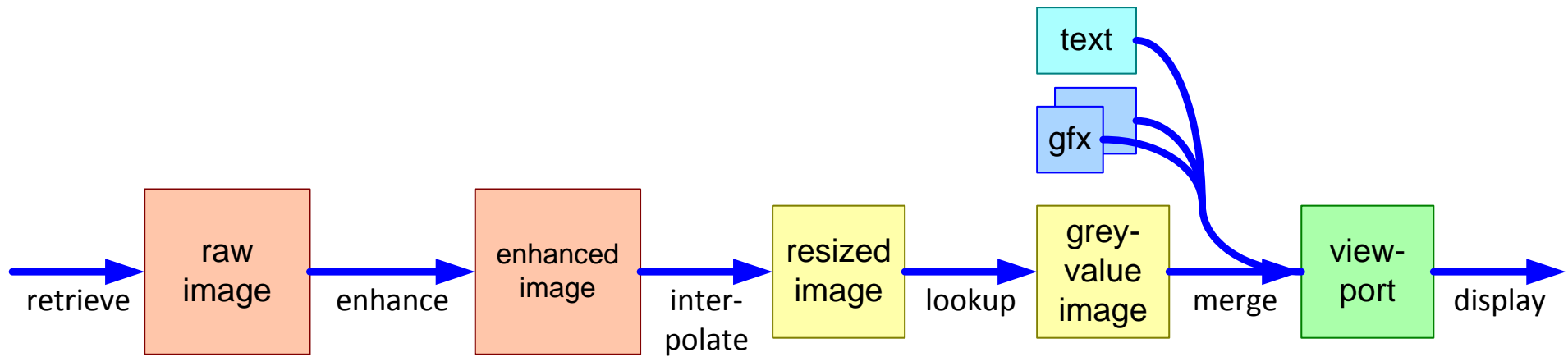
Cache layers



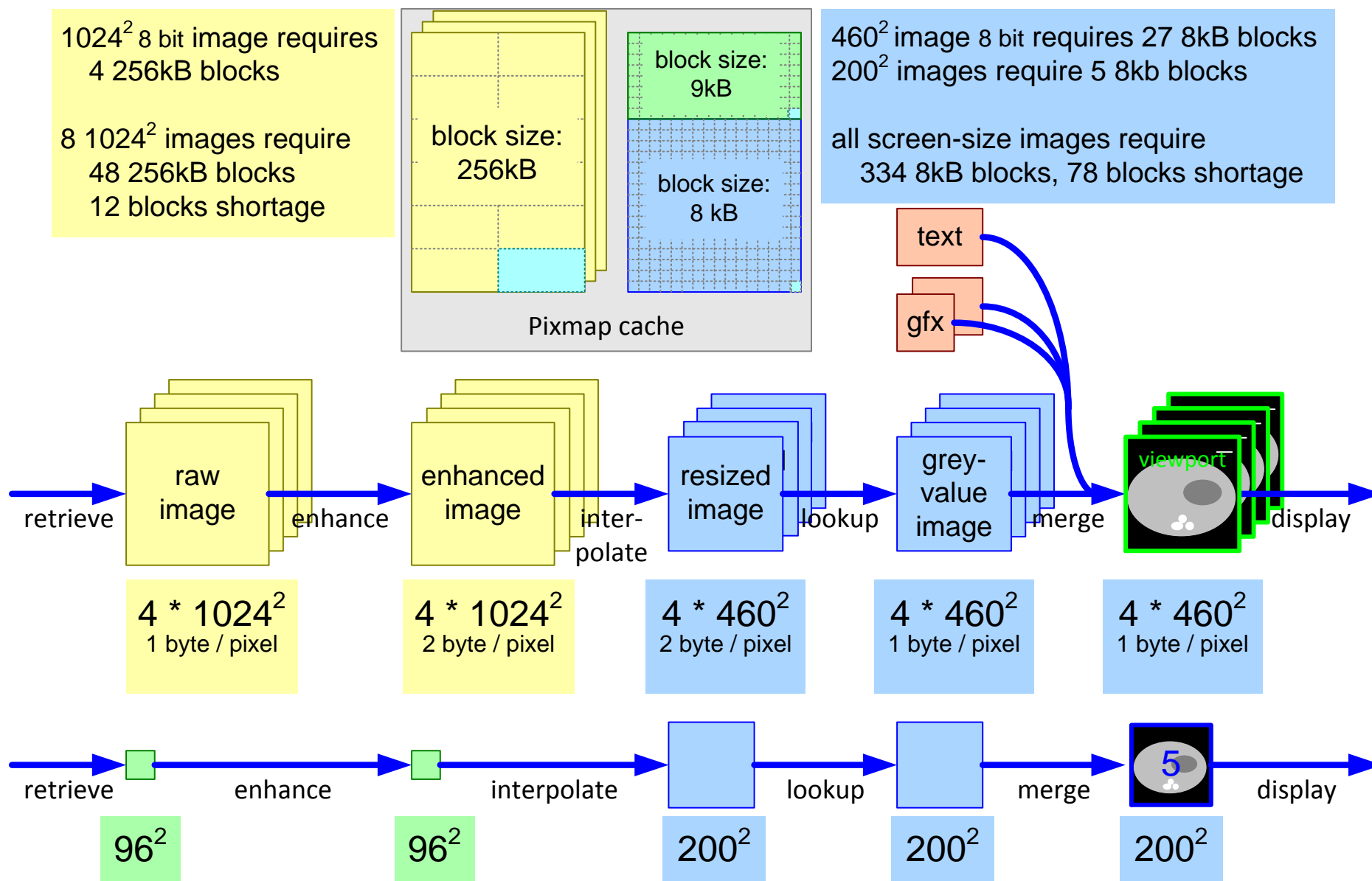
Bulk data memory management memory allocators



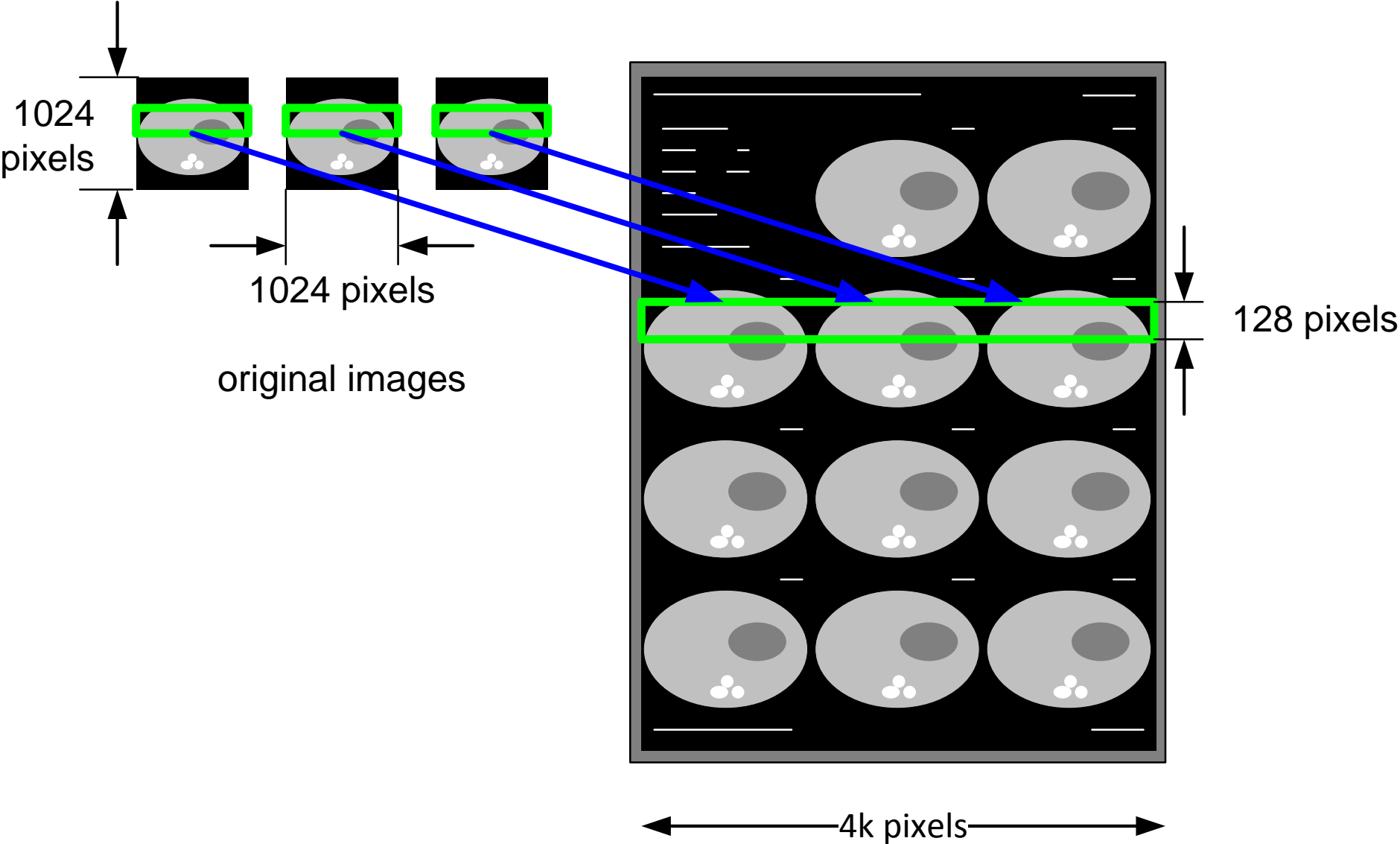
Cached intermediate processing results



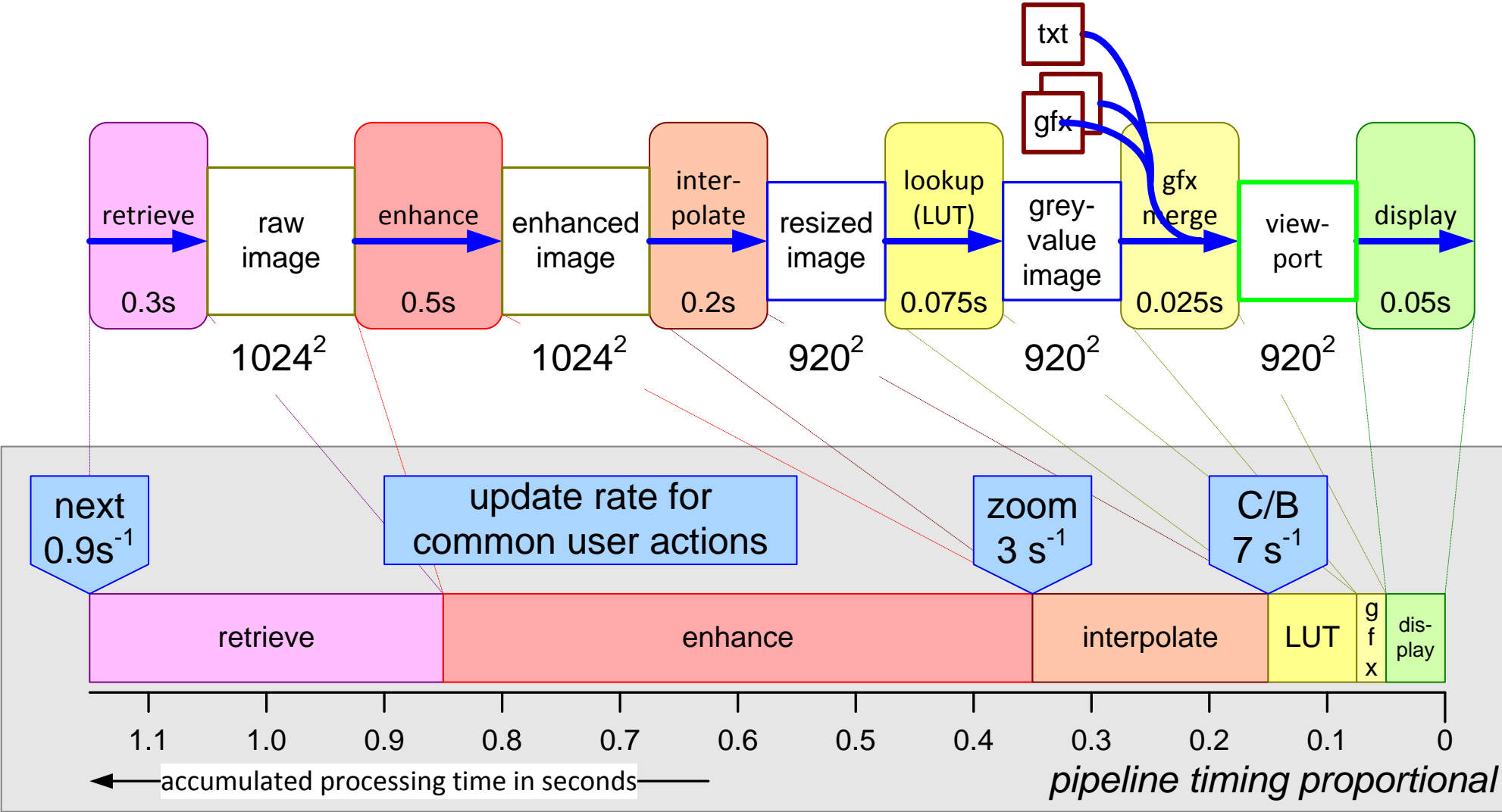
Example of allocator and cache use



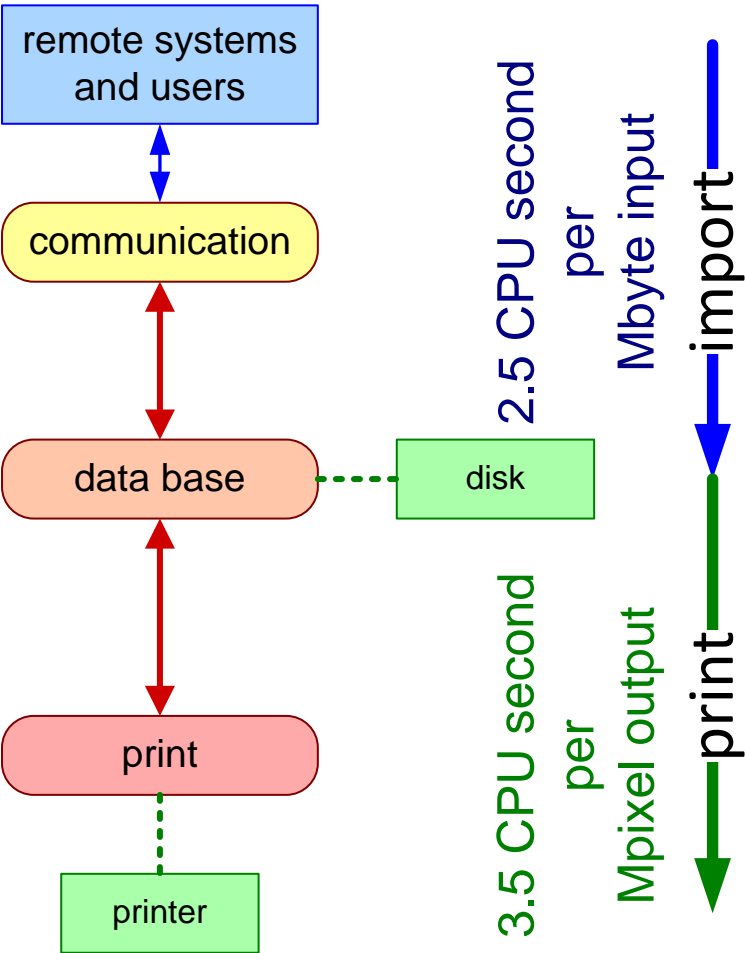
Print server is based on banding



CPU processing times and viewing responsiveness



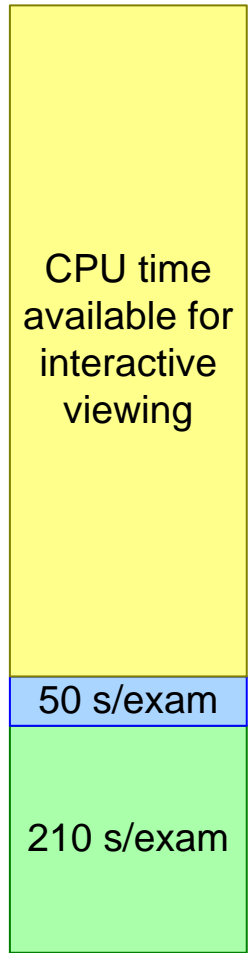
Server CPU load



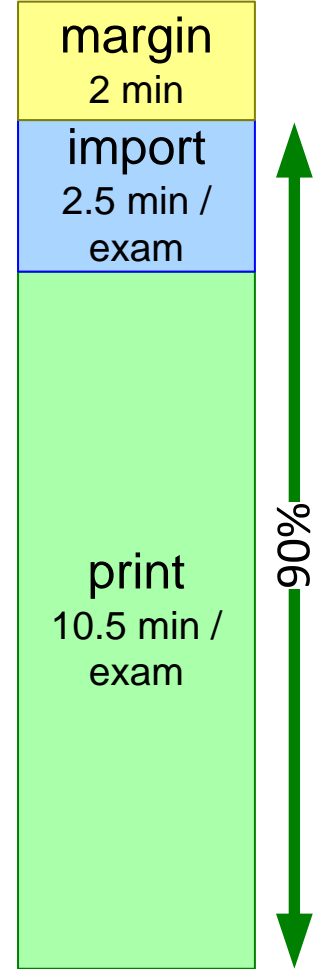
2.5 CPU second per Mbyte input

3.5 CPU second per Mpixel output

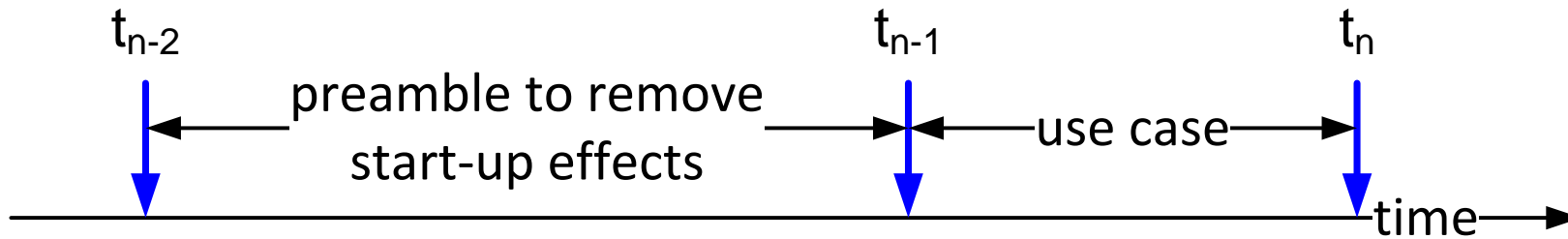
serving one examination room



serving 3 examination rooms



Resource measurement tools



oit △ object instantiations
heap memory usage

ps
vmstat
kernel resource
stats kernel CPU time
user CPU time
code memory
virtual memory
paging

heapviewer (visualise fragmentation)

Object Instantiation Tracing

class name	current nr of objects	deleted since t_{n-1}	created since t_{n-1}	heap memory usage
AsynchronousIO	0	-3	+3	
AttributeEntry	237	-1	+5	
BitMap	21	-4	+8	
BoundedFloatingPoint	1034	-3	+22	
BoundedInteger	684	-1	+9	
BTreeNode1	200	-3	+3	[819200]
BulkData	25	0	1	[8388608]
ButtonGadget	34	0	2	
ButtonStack	12	0	1	
ByteArray	156	-4	+12	[13252]

Overview of benchmarks and other measurement tools

	test / benchmark	what, why	accuracy	when
<i>public</i>	SpecInt (by suppliers)	CPU integer	coarse	new hardware
	Byte benchmark	computer platform performance OS, shell, file I/O	coarse	new hardware new OS release
<i>self made</i>	file I/O	file I/O throughput	medium	new hardware
	image processing	CPU, cache, memory as function of image, pixel size	accurate	new hardware
	Objective-C overhead	method call overhead memory overhead	accurate	initial
	socket, network	throughput CPU overhead	accurate	ad hoc
	data base	transaction overhead query behaviour	accurate	ad hoc
	load test	throughput, CPU, memory	accurate	regression

Coverage of submethods of the CR views

C onceptual	R ealization
<p><i>construction decomposition</i> <i>functional decomposition</i> <i>designing with multiple decompositions</i> <i>execution architecture</i> <i>internal interfaces</i> <i>performance</i> <i>start up</i> <i>shutdown</i> <i>integration plan</i></p> <p>work breakdown safety</p> <p>reliability security</p>	<p><i>budget</i> <i>benchmarking</i> <i>performance analysis</i> <i>granularity determination</i></p> <p>value and cost</p> <p>safety analysis reliability analysis security analysis</p>

legend *explicitly addressed* **addressed only implicitly** not addressed

coverage based on documentation status of first product release

disclaimer

The case material is based on actual data, from a complex context with large commercial interests. The material is ***simplified*** to increase the accessibility, while at the same time ***small changes*** have been made to remove commercial sensitivity. Commercial sensitivity is further reduced by using relatively ***old*** data (between 5 and 10 years in the past). Care has been taken that the illustrative value is maintained

Story Telling in Medical Imaging

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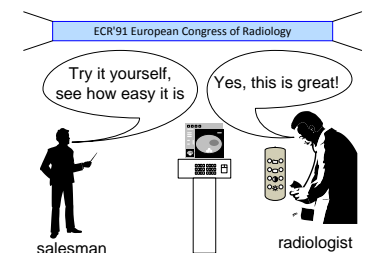
Abstract

Story telling was not used explicit during the development of the medical imaging workstation. Two stories which did have a great impact of the development of the product are described: “The sales story” and “The radiologist at work”. The relation of the stories to the requirements and design is shown.

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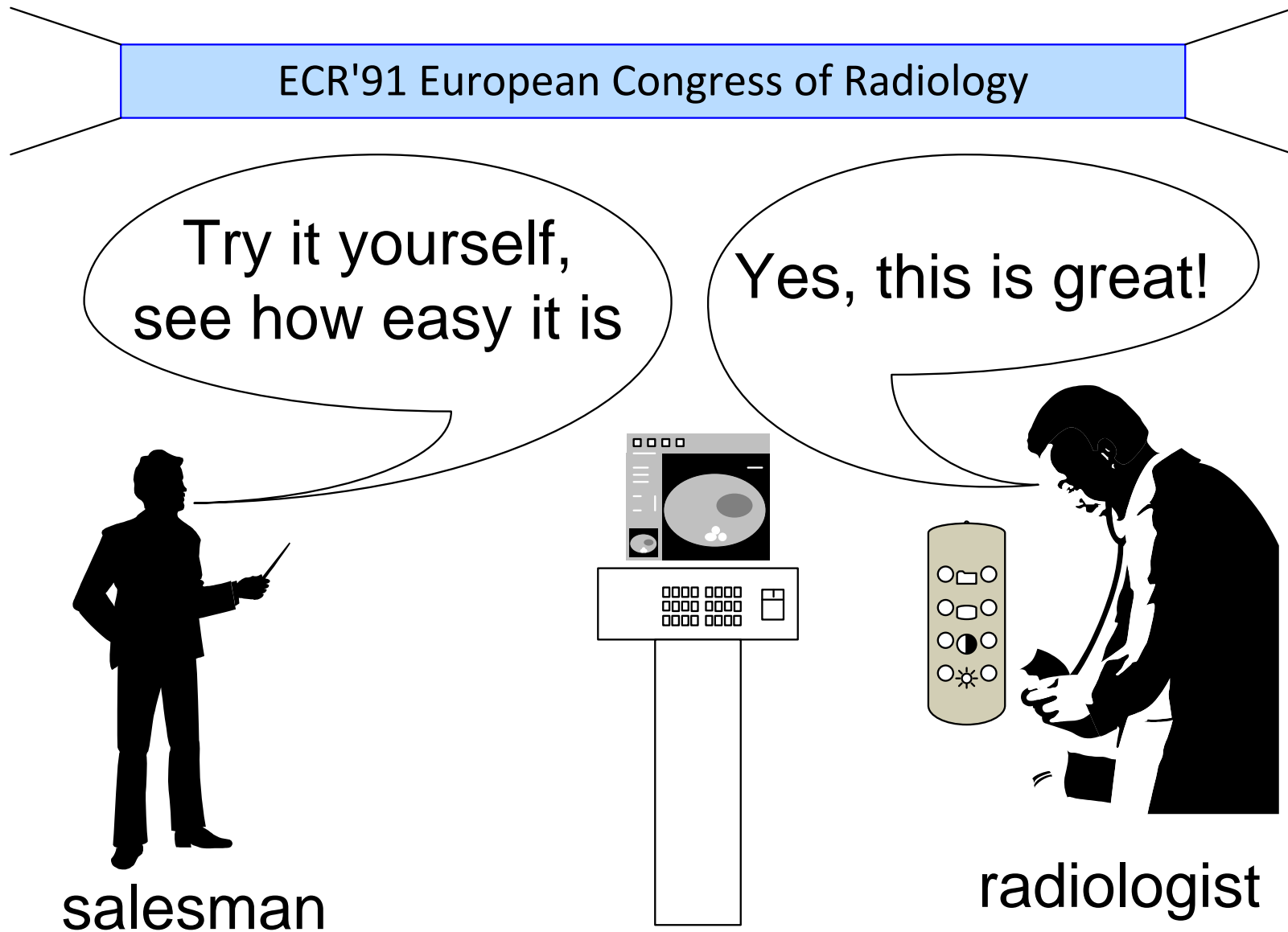
Stories used during development

The sales story how to capture the interest of the radiologist for the product.

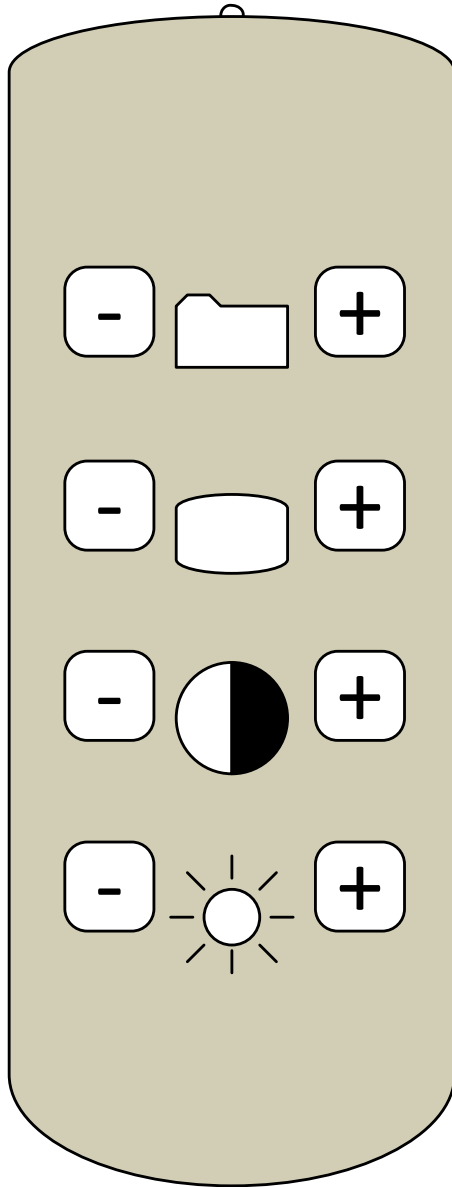
The radiologist at work describing the way a radiologist works, which explains why the radiologist is **not** interested in viewing, but very interested in films.

The gastro intestinal examination how the URF system is used to examine patients with gastro intestinal problems. This story is not described here, because it is outside the scope of the discussed thread of reasoning

Main sales feature: easy viewing



Remote control makes viewing easy



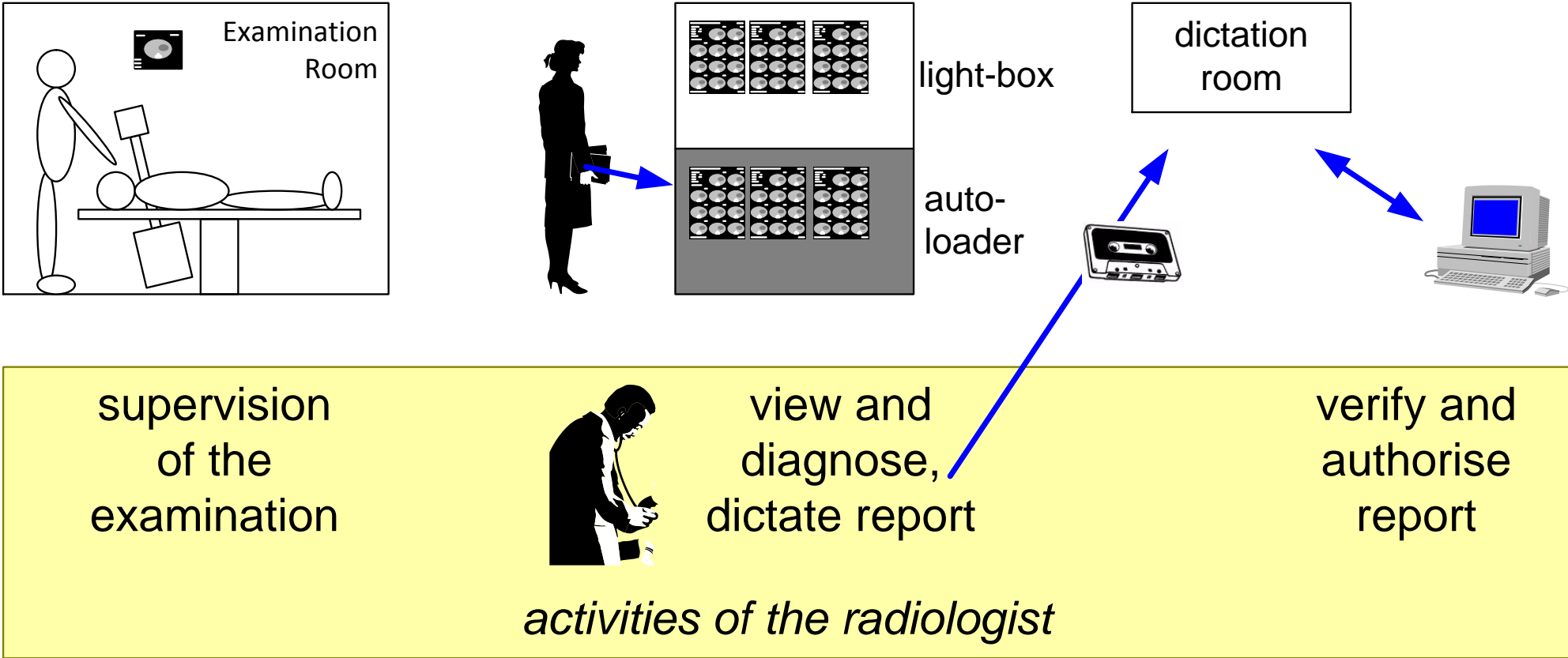
next / previous examination

next / previous image

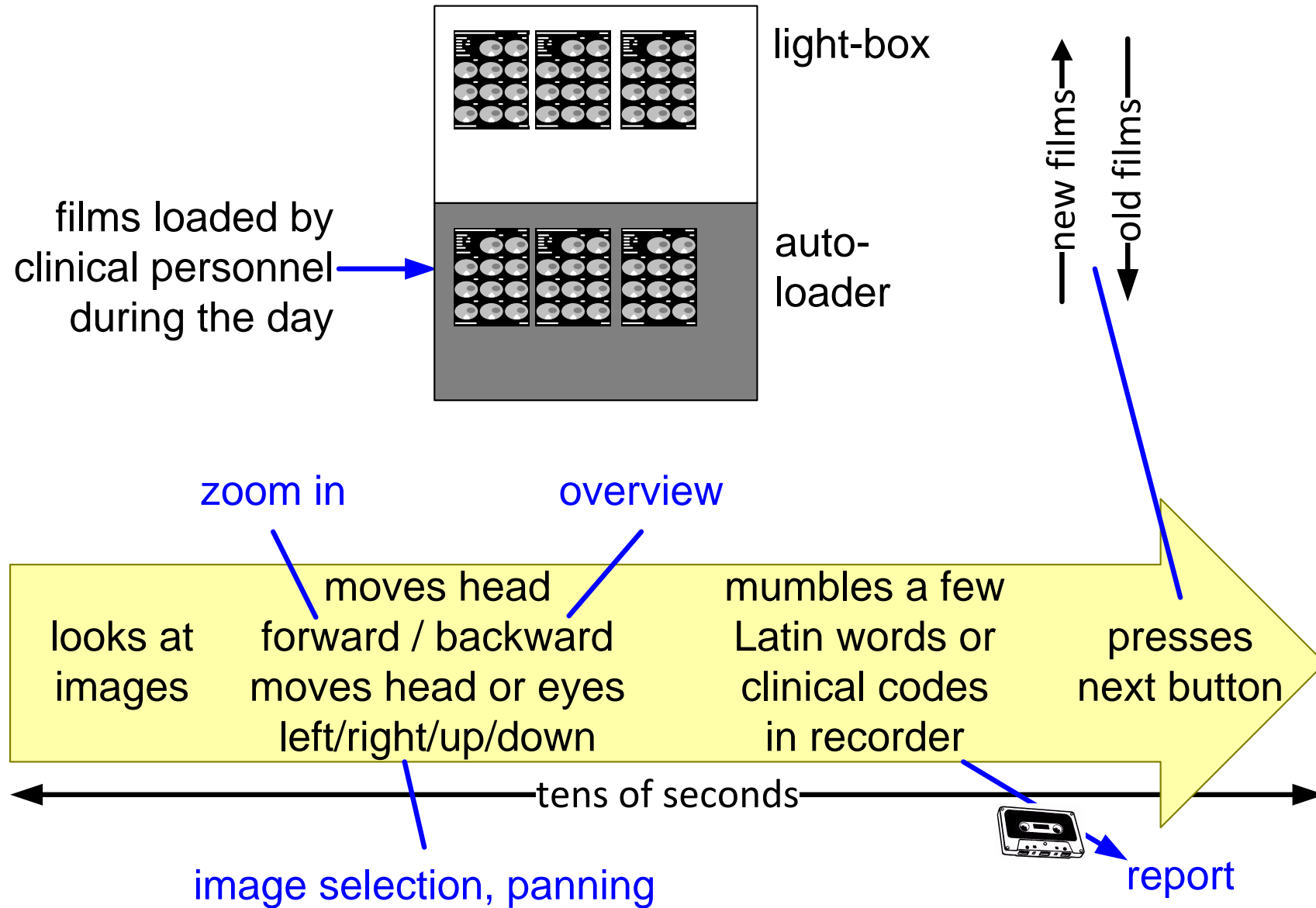
increase / decrease contrast

increase / decrease brightness

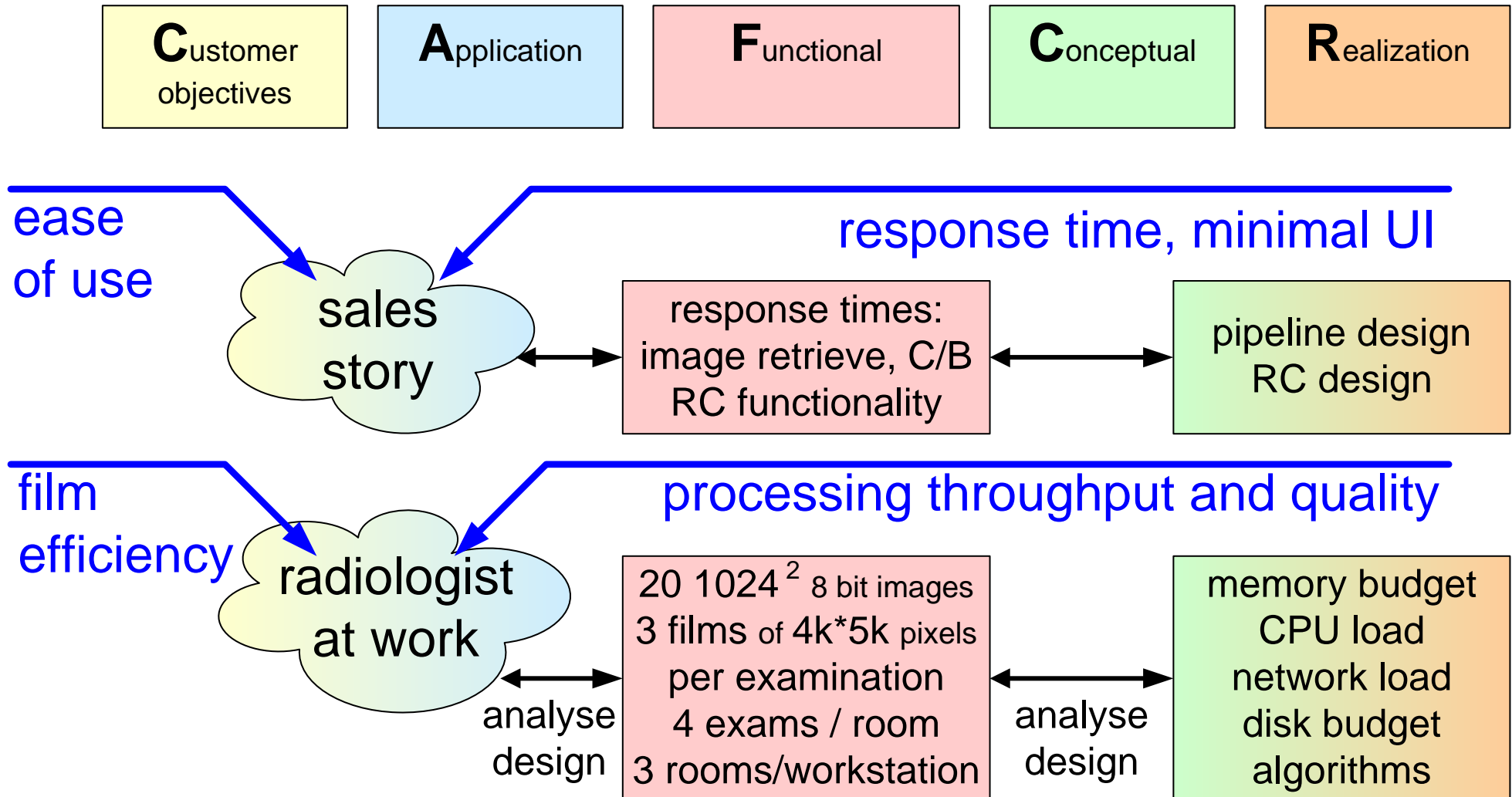
Radiologist workspots and activities



Diagnosis in tens of seconds



From story to design



Threads of Reasoning in the Medical Imaging Case

by *Gerrit Muller* University of South-Eastern Norway-NISE

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www.gaudisite.nl

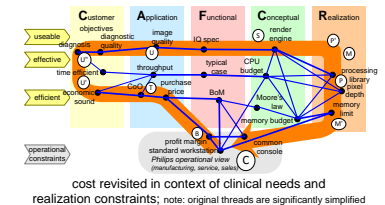
Abstract

A thread of reasoning is build up in steps and the underlying reasoning is explained.

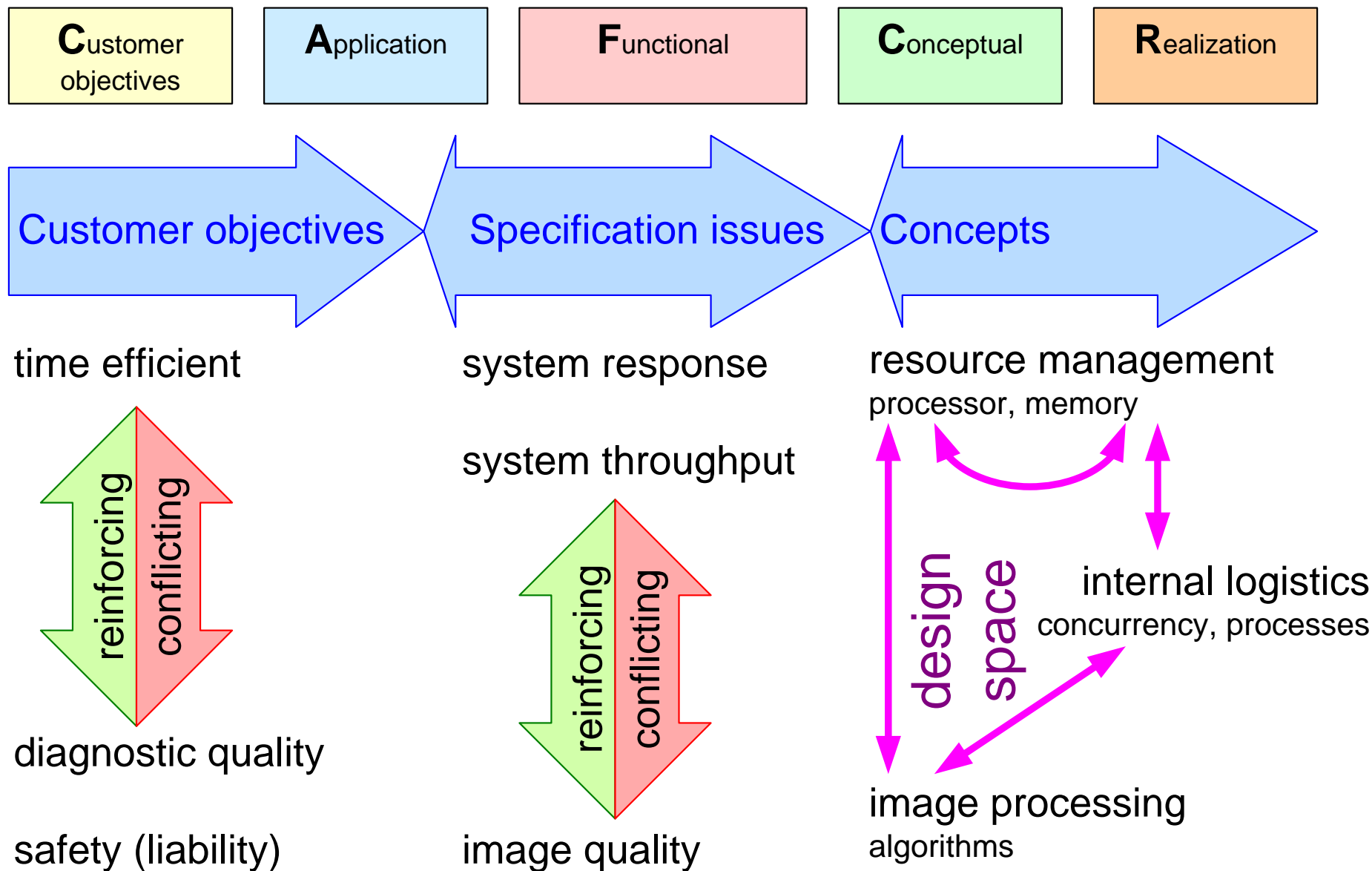
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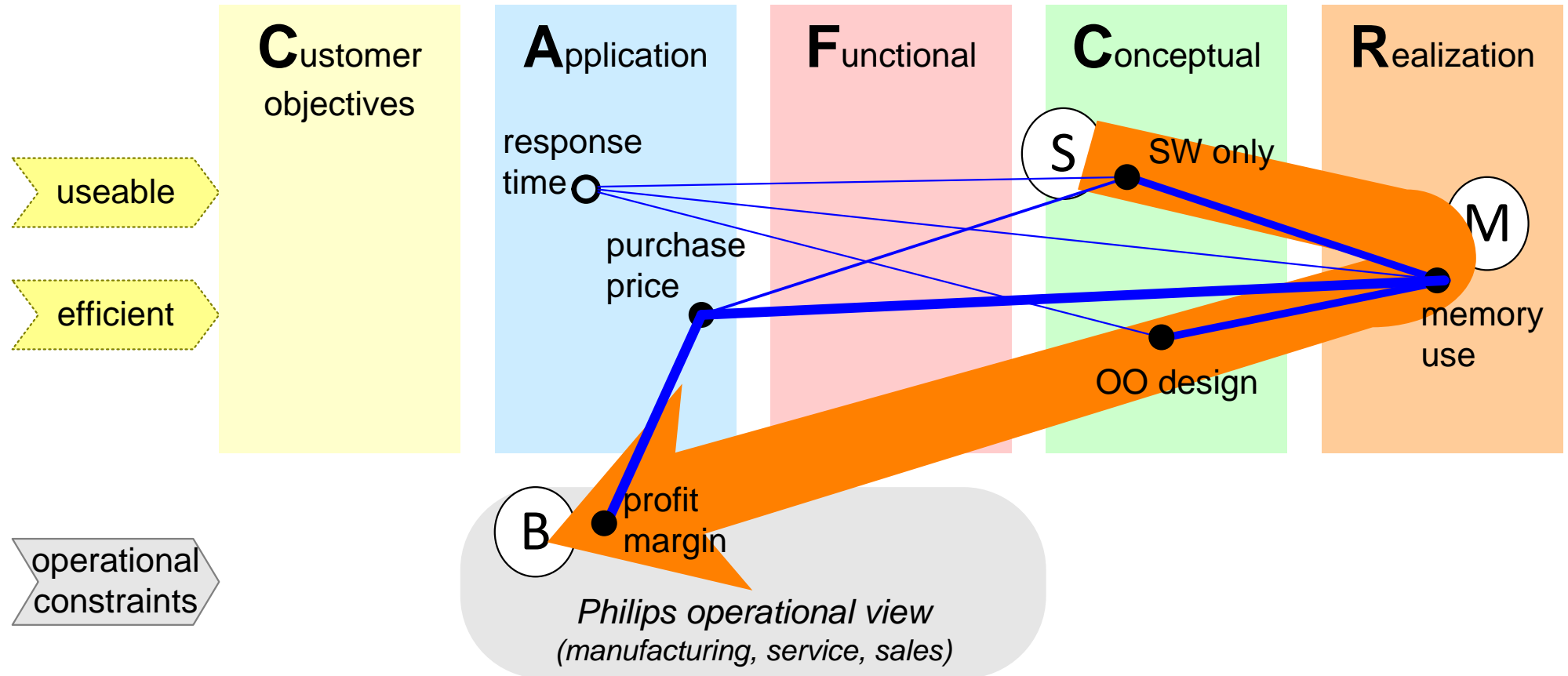
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version: 2.4



Thread of reasoning based on efficiency-quality tension

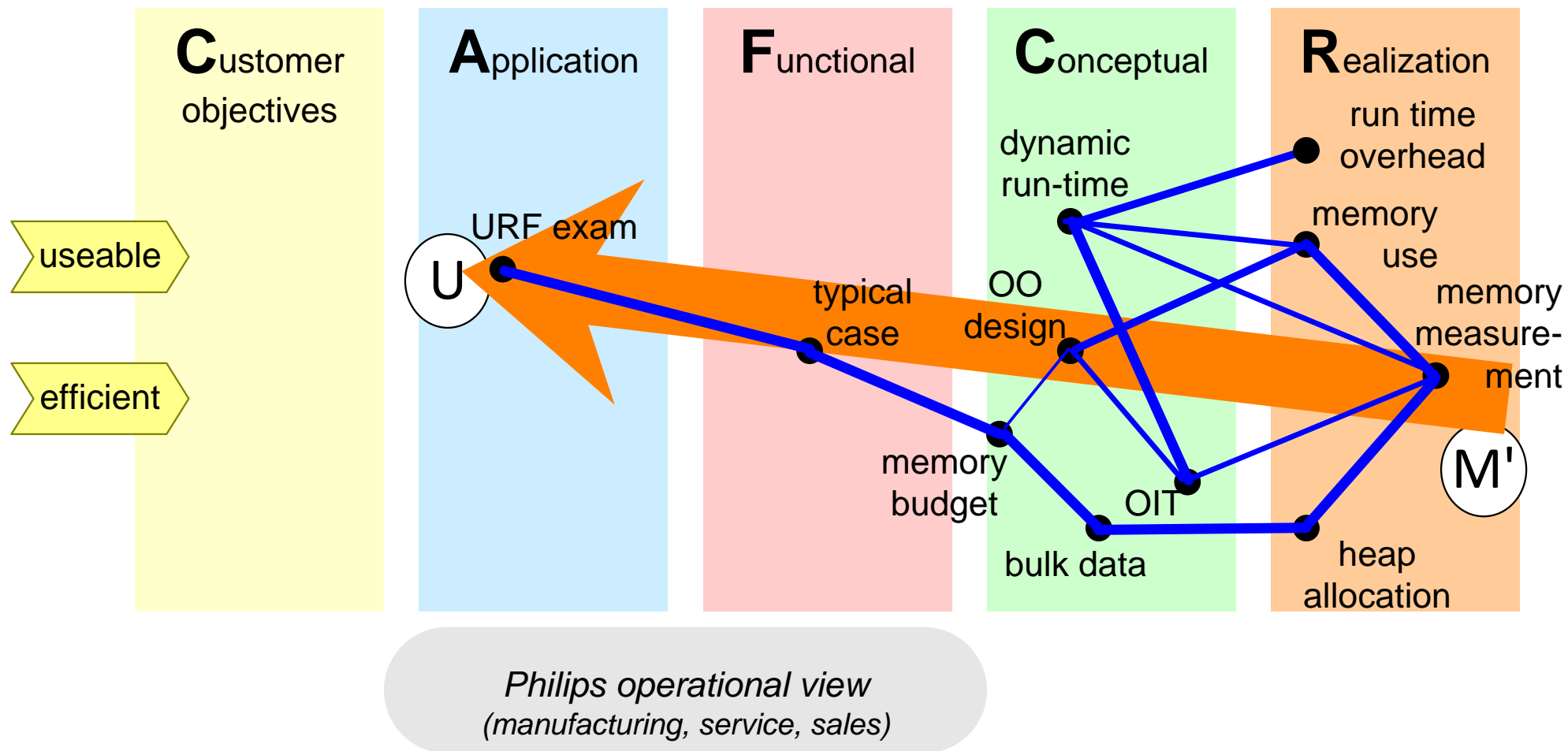


Thread of reasoning; introvert phase



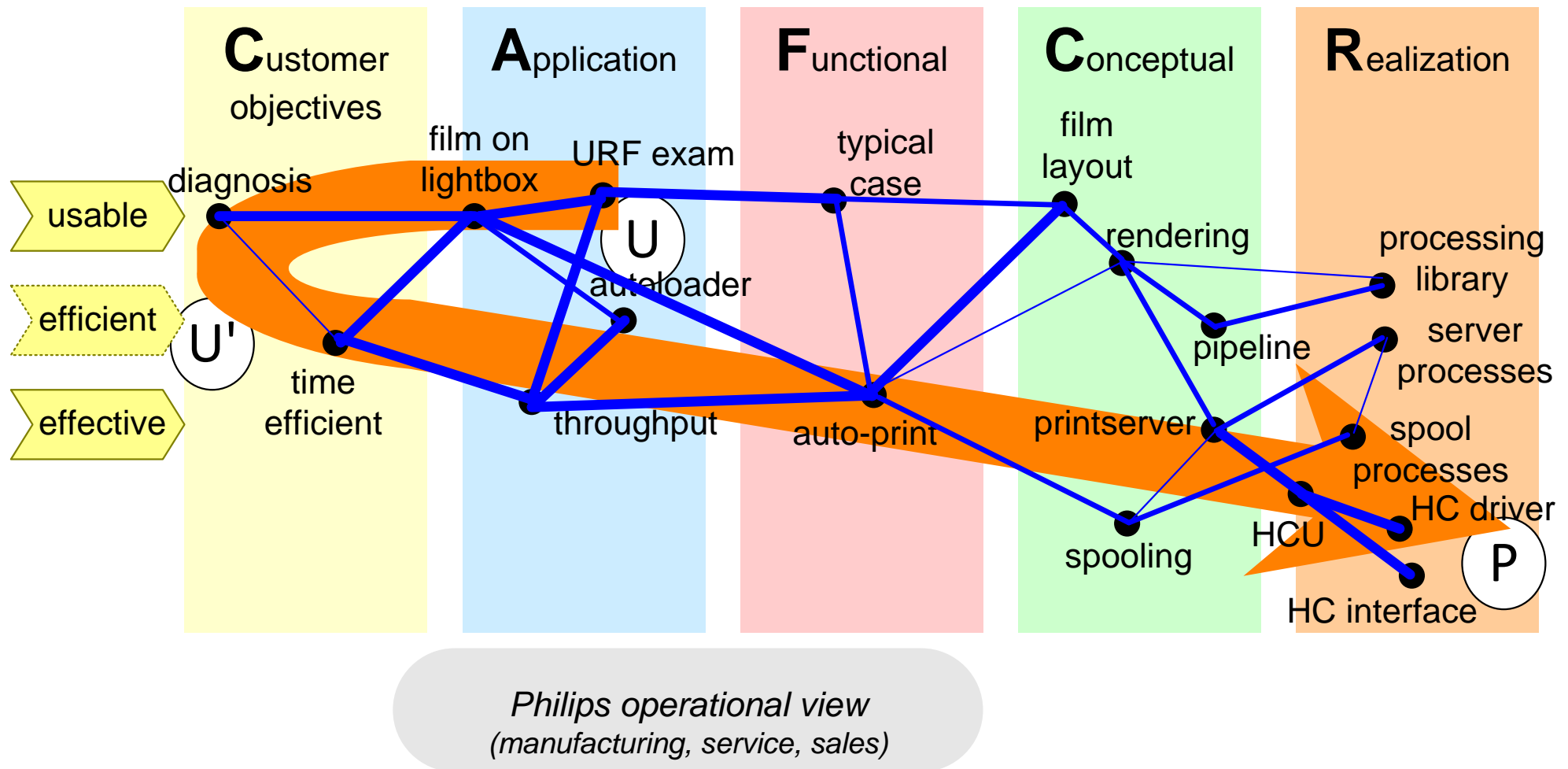
Introvert view: cost and impact of new technologies

Thread of reasoning; phase 2



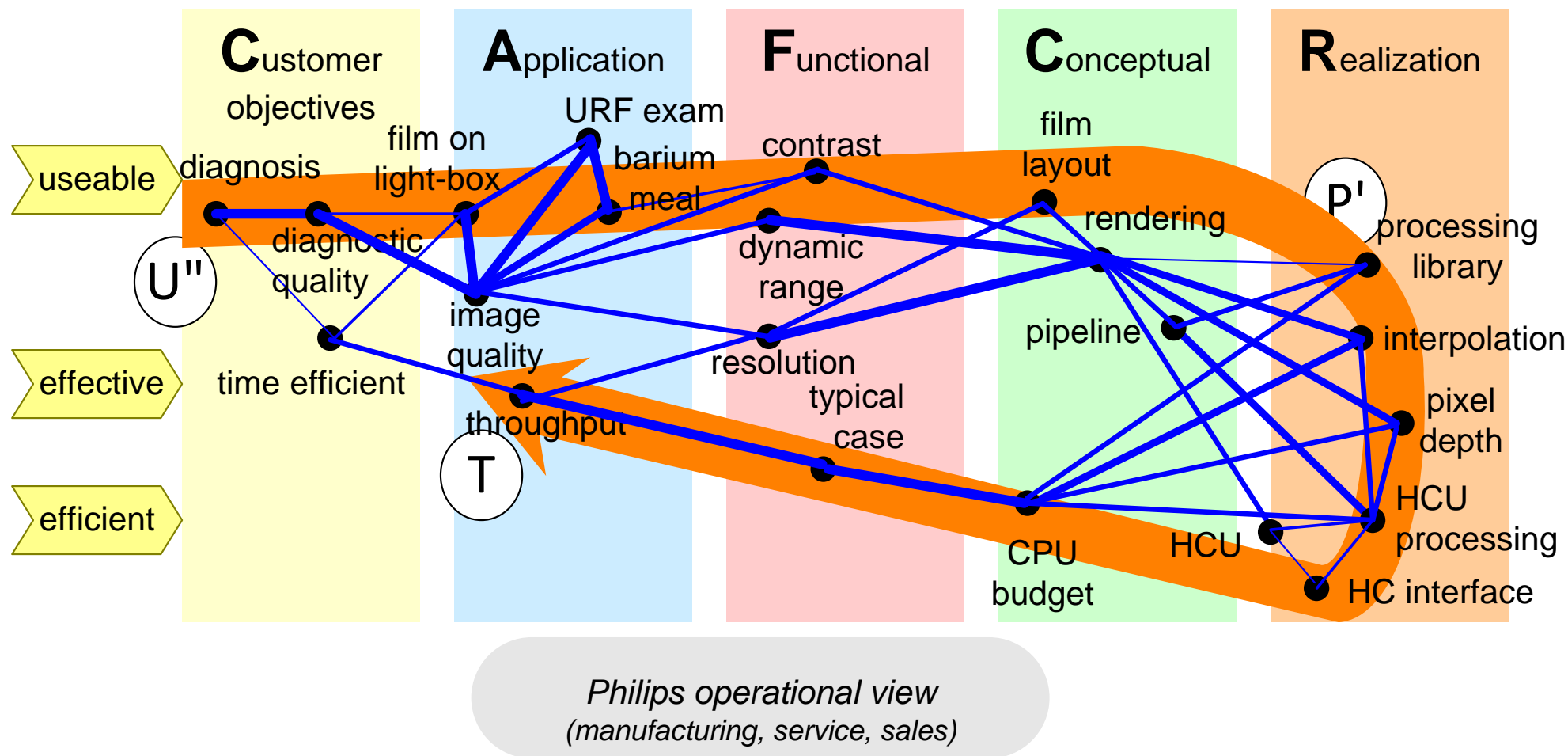
How to measure memory, how much is needed?
from introvert to extrovert

Thread of reasoning; phase 3



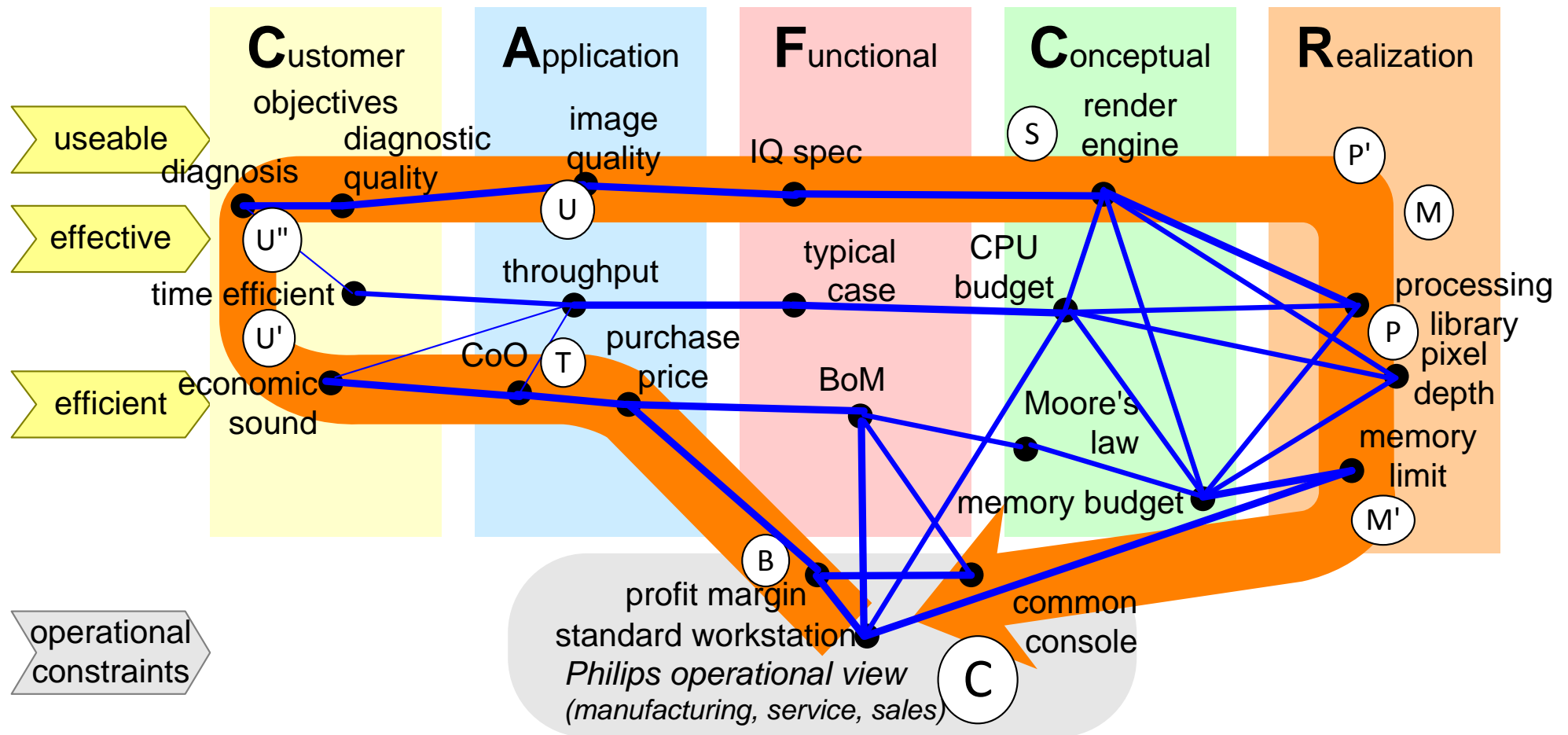
Radiologists diagnose from film, throughput is important
Extrovert view shows conceptual and realization gaps!

Thread of reasoning; phase 4



from extrovert diagnostic quality, via image quality, algorithms and load, to extrovert throughput

Thread of reasoning; phase 5



cost revisited in context of clinical needs and realization constraints; note: original threads are significantly simplified