Soft Real Time Design

by *Gerrit Muller* HSN-NISE
e-mail: gaudisite@gmail.com
www.gaudisite.nl

Abstract

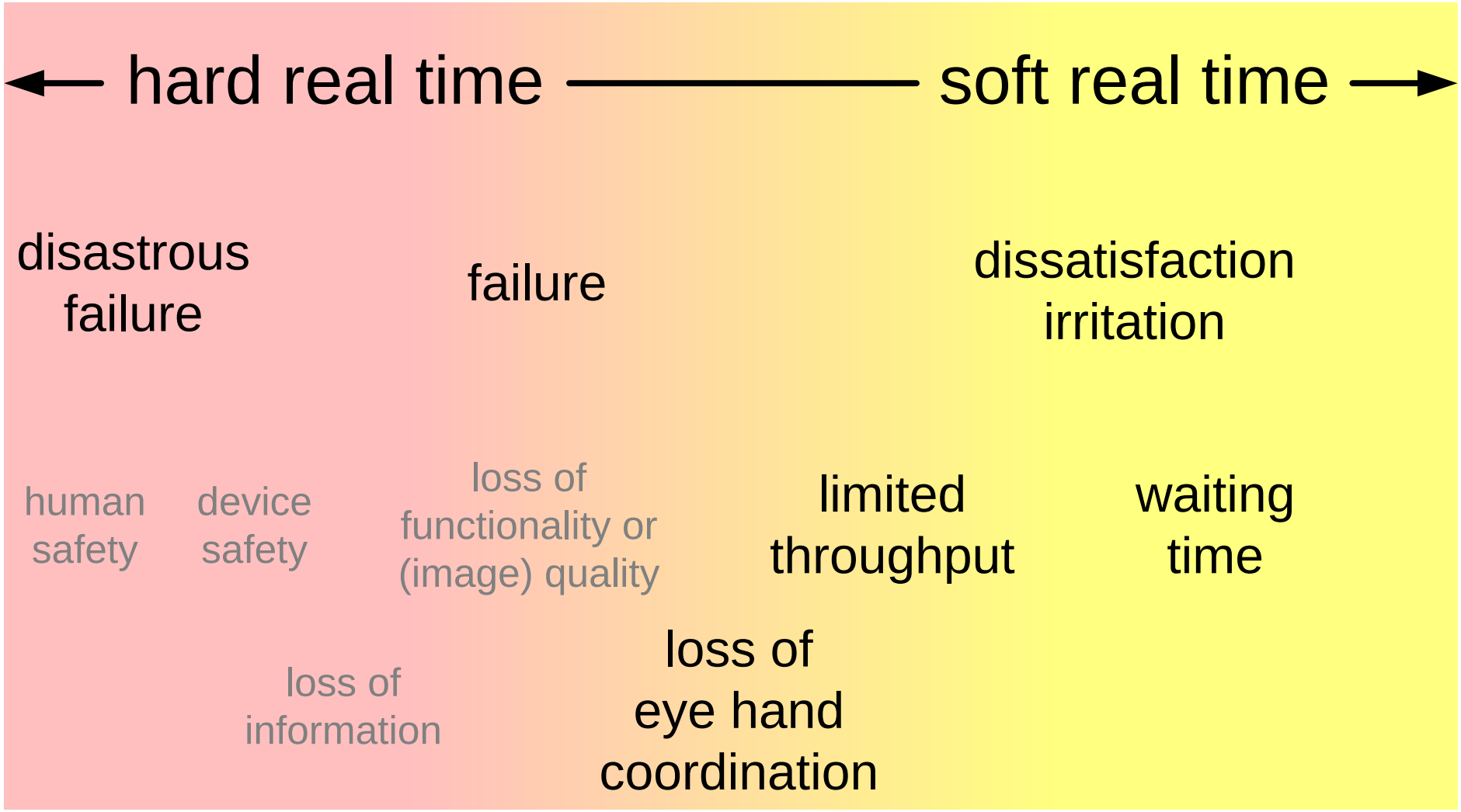
Soft Real Time design addresses the performance aspects of the system design, under the assumption that the hard real time design is already well-covered. Core decisions in soft real time design are:

- granularity
- synchronization
- prioritization
- allocation
- resource management

August 16, 2025
status: preliminary draft
version: 0.2

The complete course ASP™ is owned by TNO-ESI. To teach this course a license from TNO-ESI is required. This material is preliminary course material.

Soft Real Time Design



Case 1

TV zapping

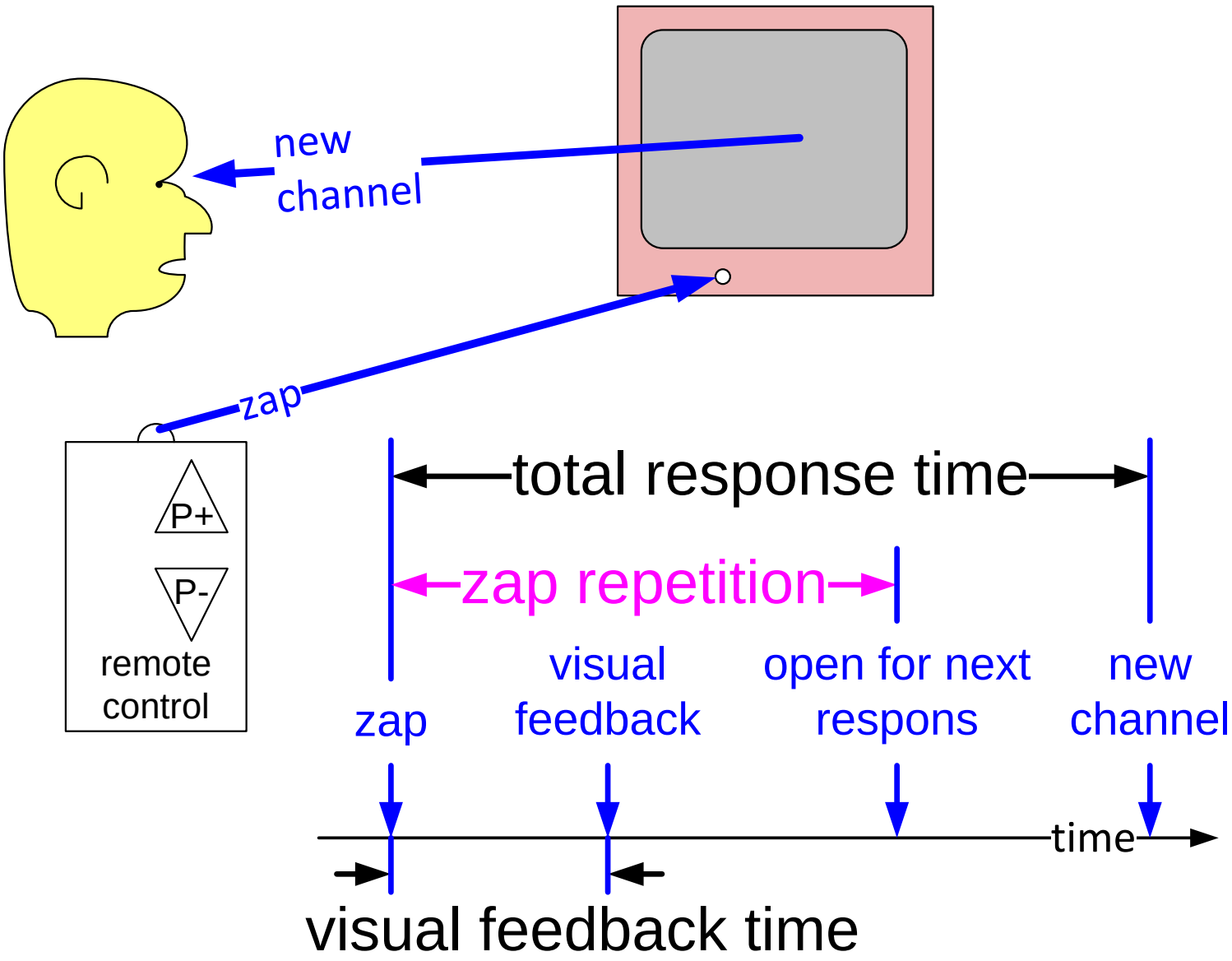
Problem introduction

Approach for solving response time problems

Revised functional model

Measuring and modelling

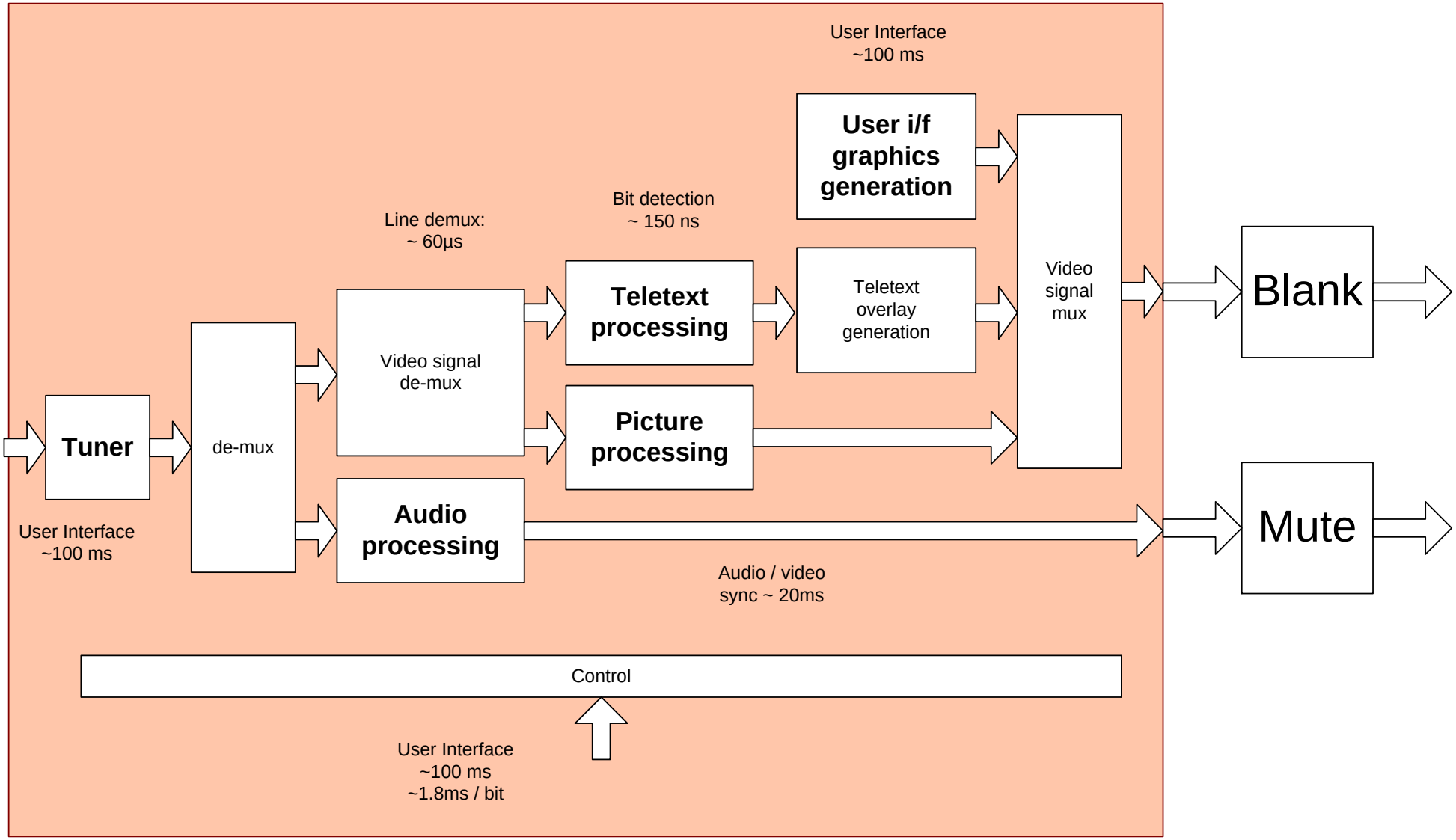
Zap timing: What is the Requirement?



Approach

1) Measure the end-to-end time
2) Decompose the processes based on expected outcome
3) Measure the individual components use previous decomposition (2)
4) Clarify the unknown parts and make them explicit
5) Further divide the major posts
6) Aggregate the smaller posts

Functional Model



Expectated and Measured Values

Expected values:

Mute	: 50 ms	
Blank	: 40 ms	*1 frame*
Flush AV pipeline	: 160 ms	*4 frames*
Set tuner	: 200 ms	
Fill AV pipeline	: 160 ms	*4 frames*
Unmute	: 50 ms	
Unblank	: 40 ms	

Measured values:

Mute	: 60 ms	
Blank	: 120 ms	
Flush AV pipeline	: 0 ms	
Set tuner	: 180 ms	
Fill AV pipeline	: 40 ms	*1 frame*
Format detection	: 200 ms	*5 frames*
Unmute	: 60 ms	
Unblank	: 120 ms	
Summing	: ~ 900 ms	

Total time measured: 2000 ms

Zapping Problem step 4

Somewhere 1000 ms are missing

Detection of frame size takes a long time!
+ Lots of software overhead
Analyze frame size detection and SW overhead

Zapping Problem step 5

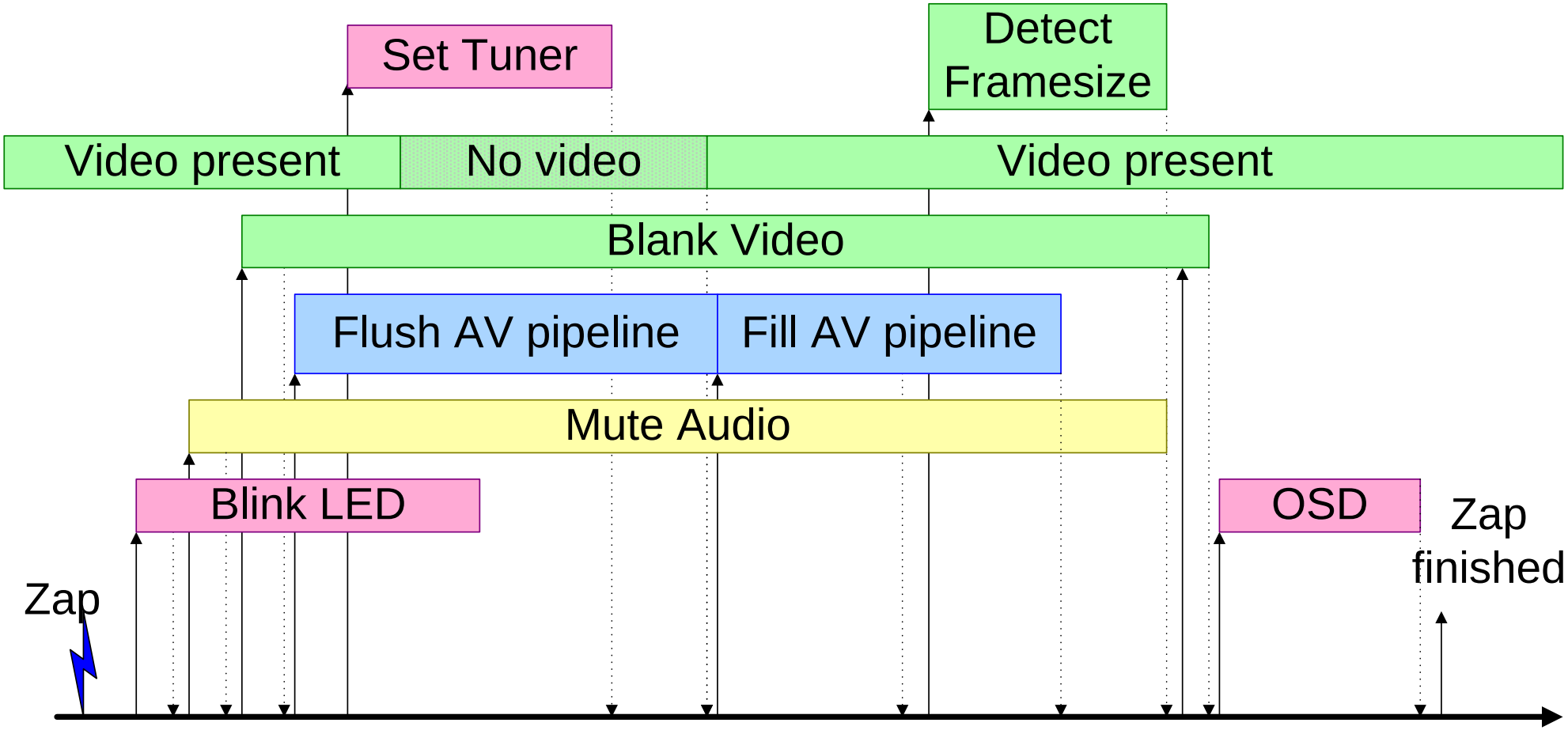
Subdivide / analyze format detection (200 ms)

Zapping Problem step 6

Ignore pipeline effects

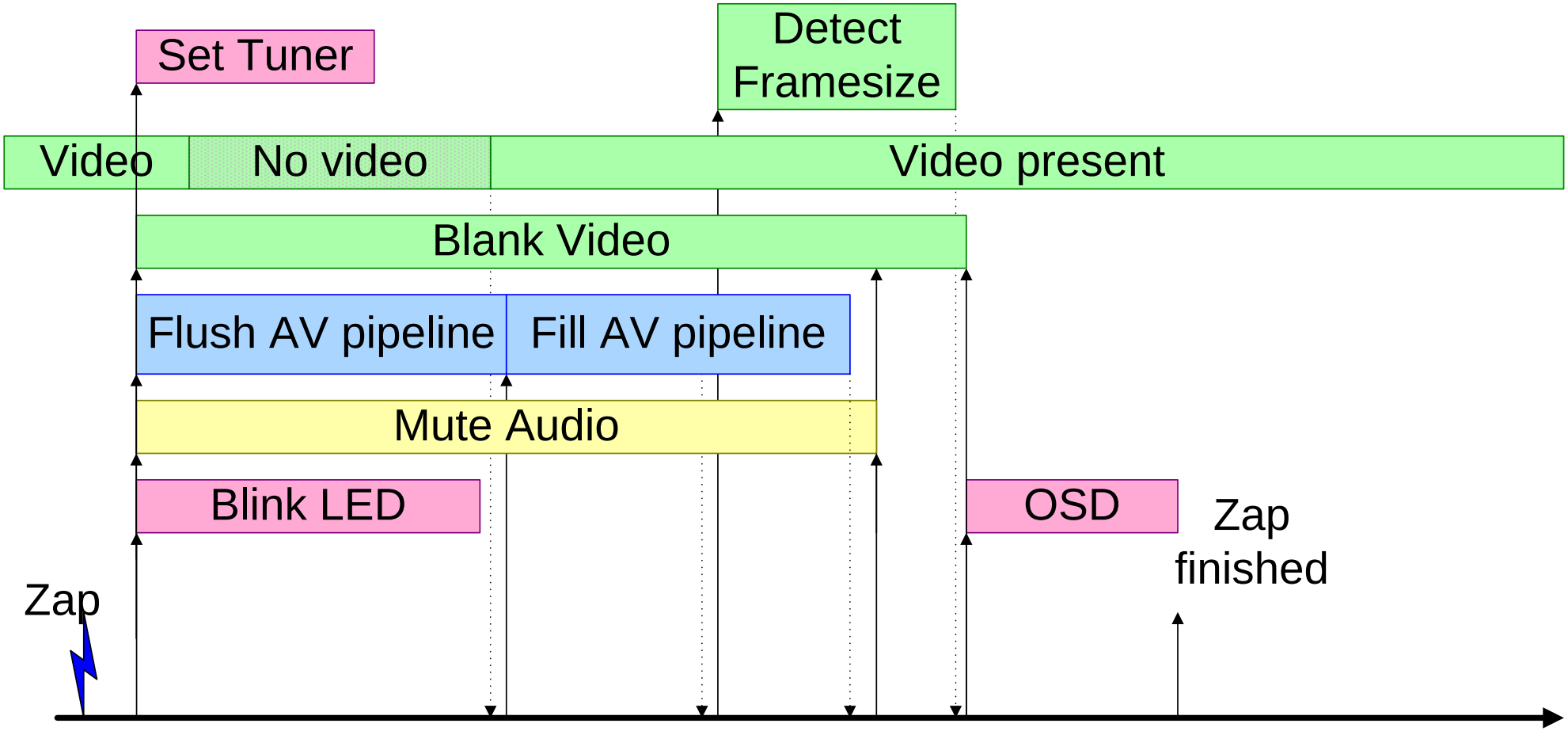
Simple Concurrency Model (with waits)

Zapping tasks sequential



Simple Concurrency Model (optimized)

Zapping tasks parallel



Case 1 Summary

TV zapping

Understanding of the problem is crucial

Iterate over modelling and measuring to build balanced performance model

EasyVision: Resource Management

Introduction to application

SW design

Memory and performance

Memory design

CPU load and Performance

Introduction to Medical Imaging Application

Easyvision

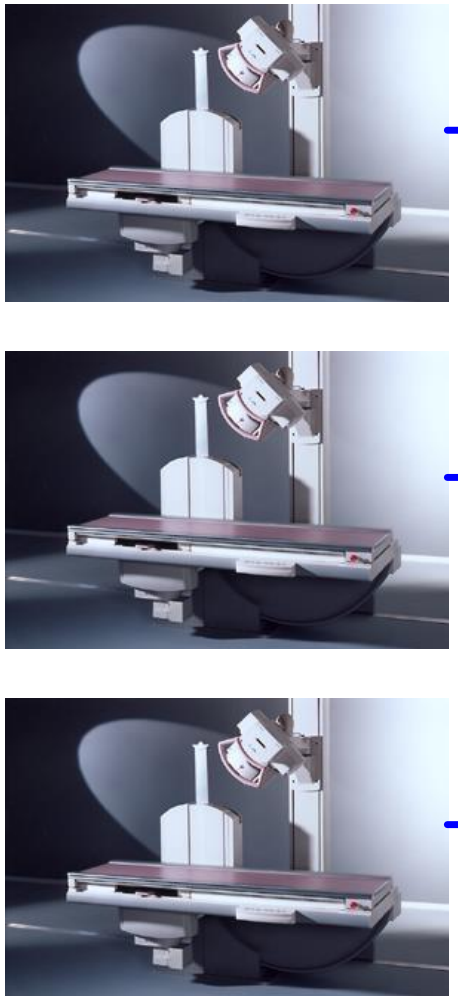
Medical Imaging Workstation

serving 3 X-ray examination rooms

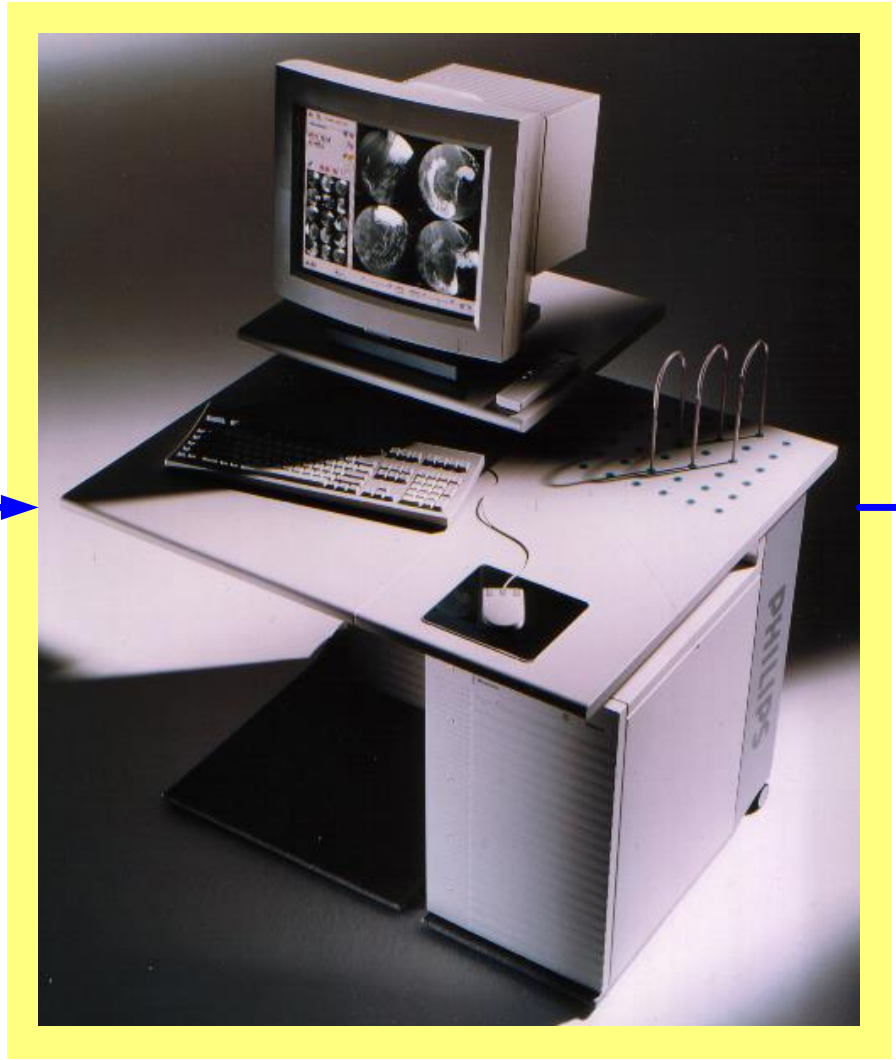
providing interactive viewing and printing on high resolution film

Challenge: interoperability and WYSIWYG over different products

Easyvision Serving Three URF Examination Rooms



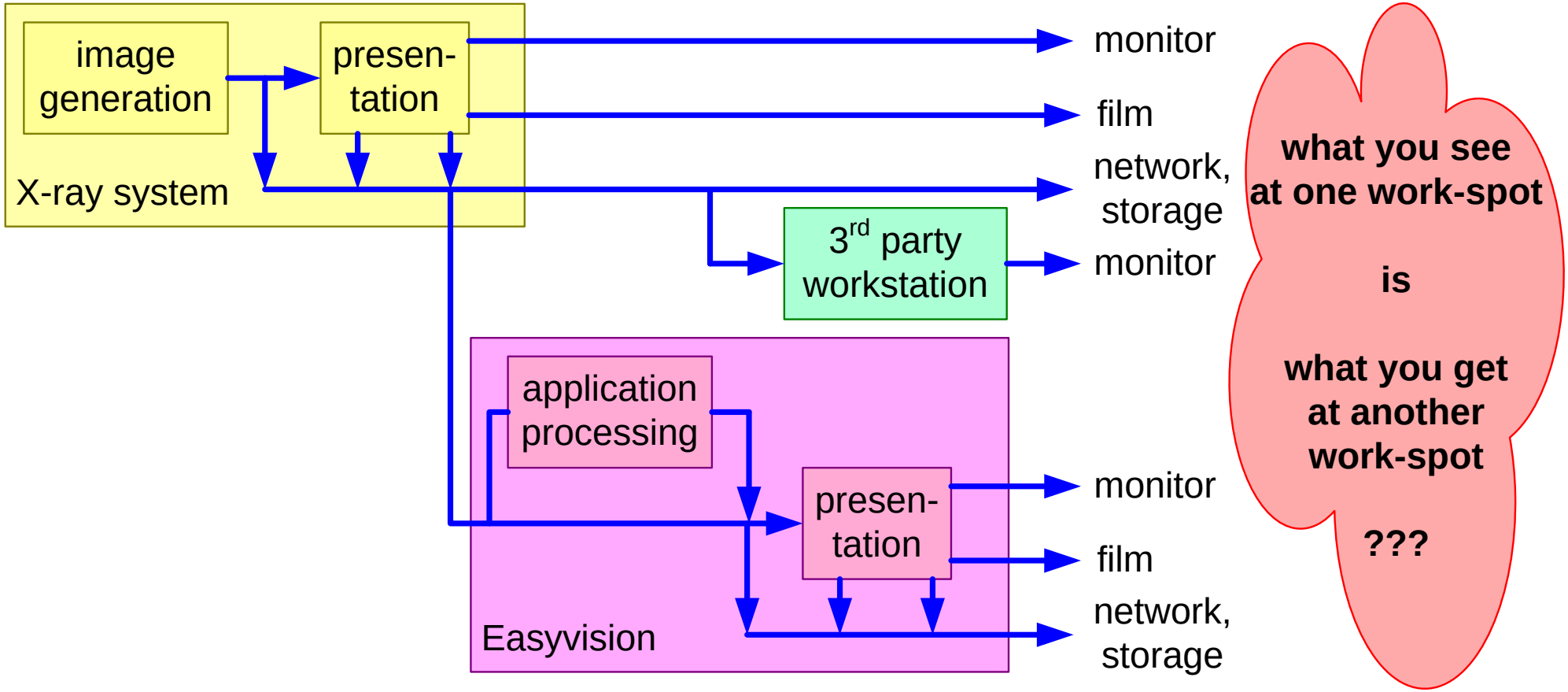
URF-systems



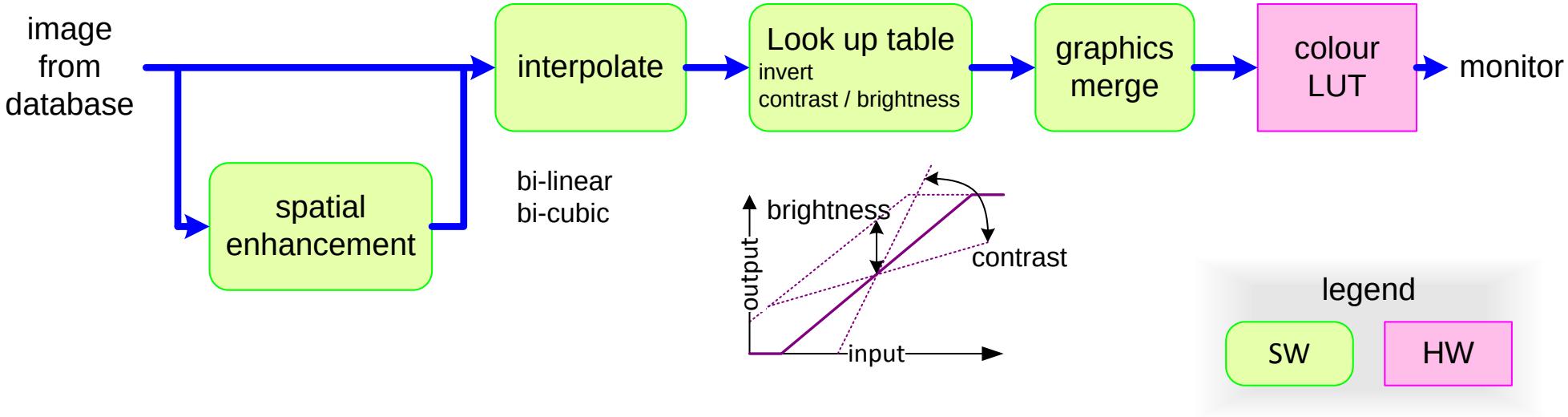
EasyVision: Medical Imaging Workstation

typical clinical image (intestines)

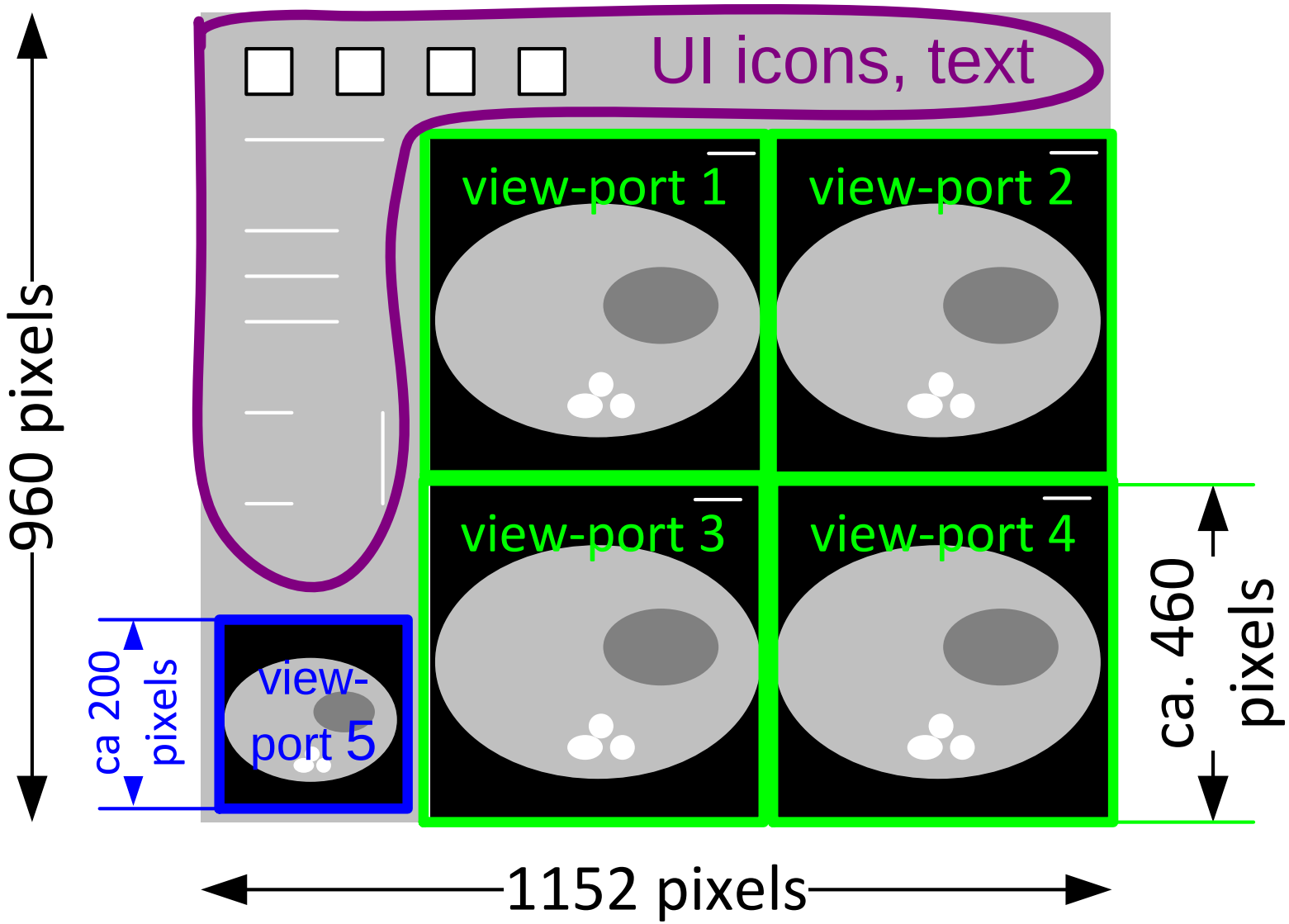
Image Quality Expectation WYSIWYG



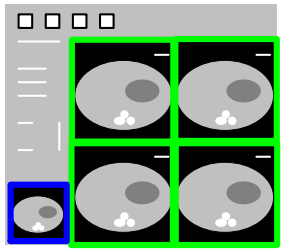
Presentation Pipeline for X-ray Images



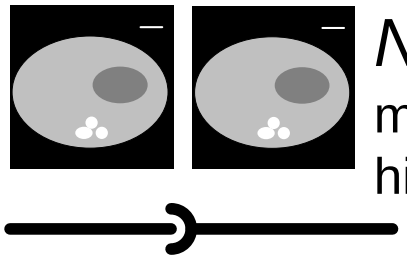
Quadruple View-port Screen Layout



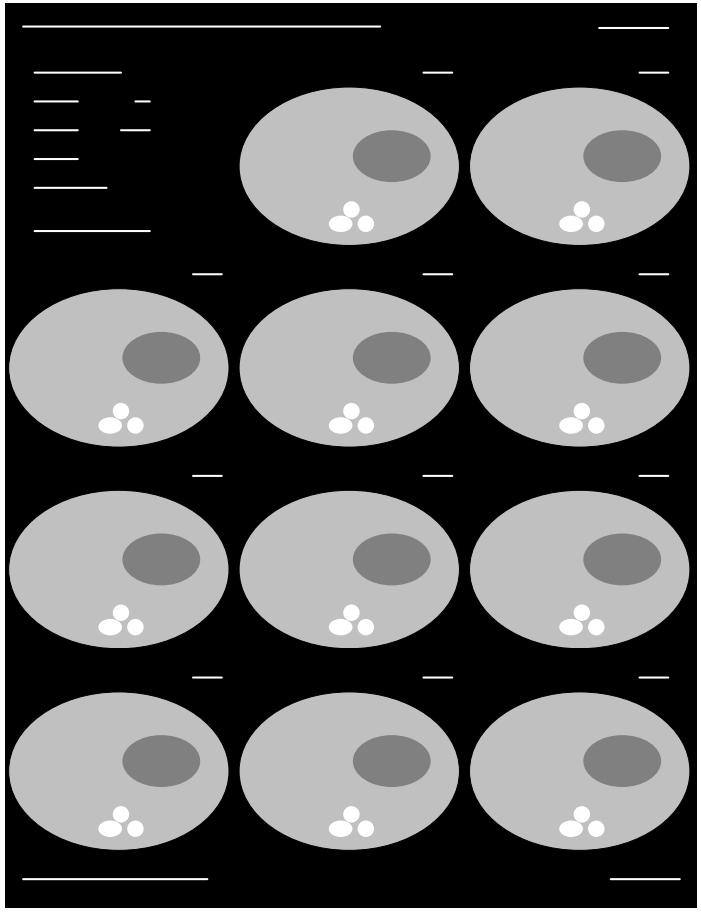
Rendered Images at Different Destinations



Screen:
low resolution
fast response



Network:
medium resolution
high throughput



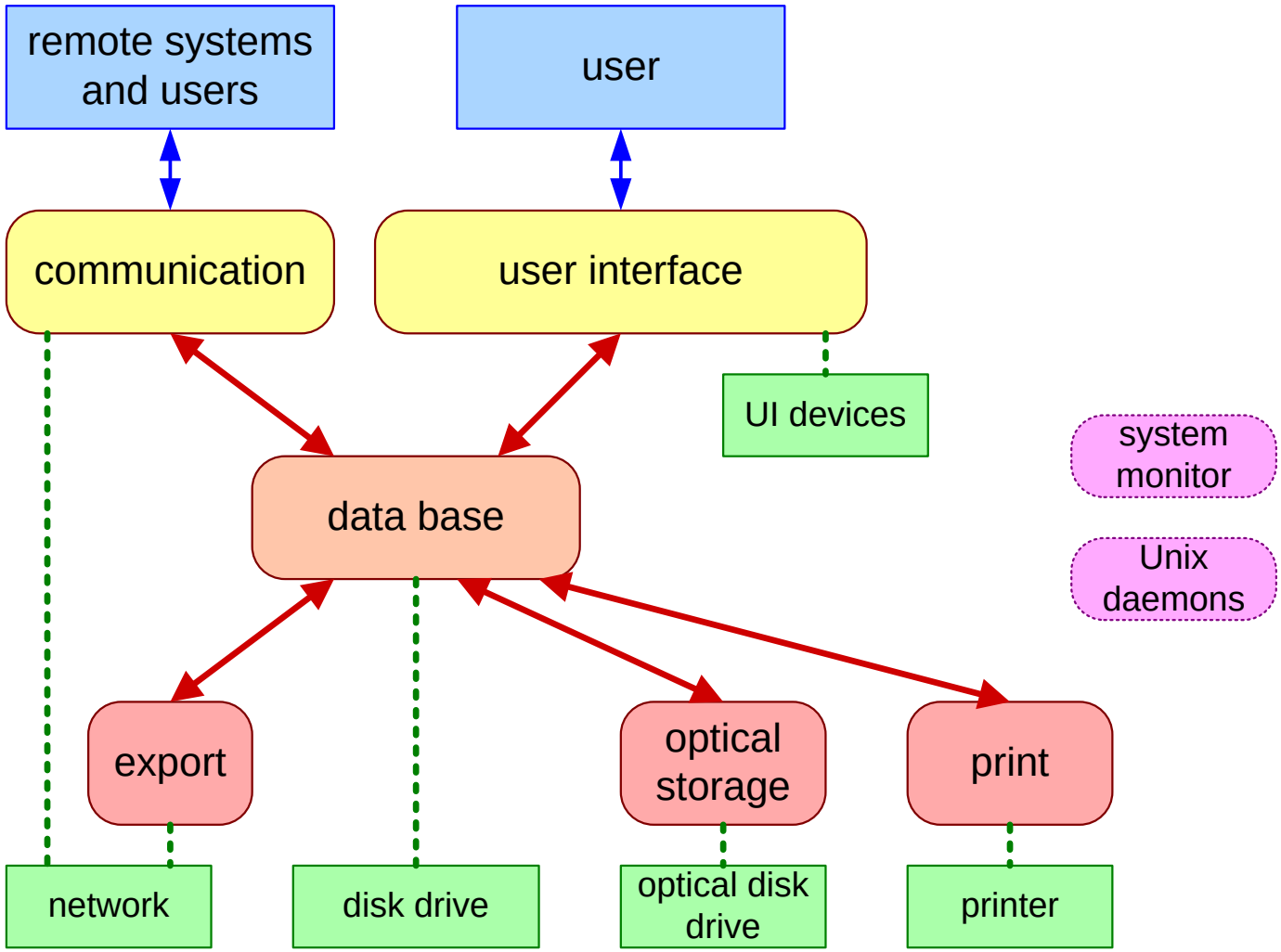
Film:
high resolution
high throughput

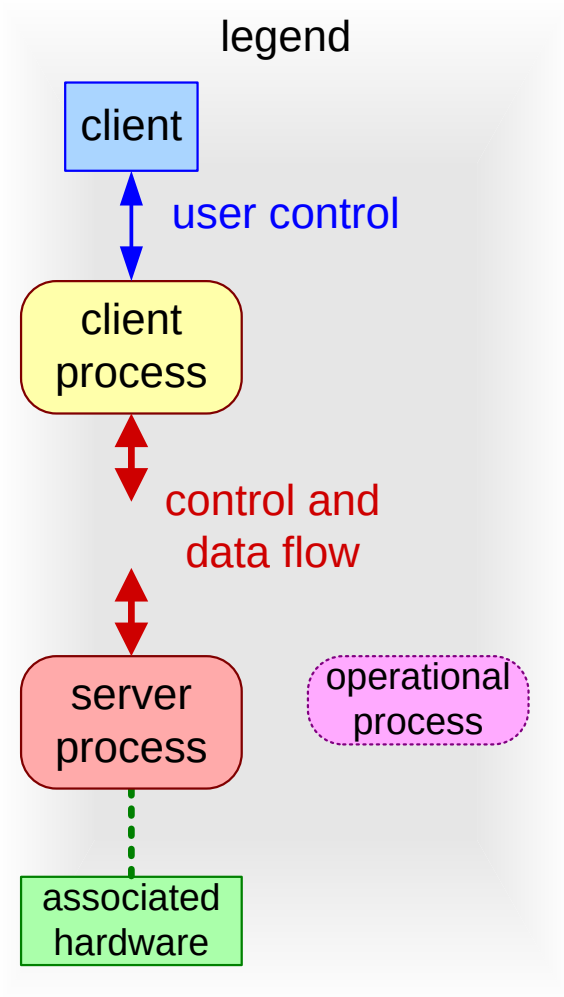
Easyvision SW design

Concurrency design

SW layers

Concurrency via Software Processes



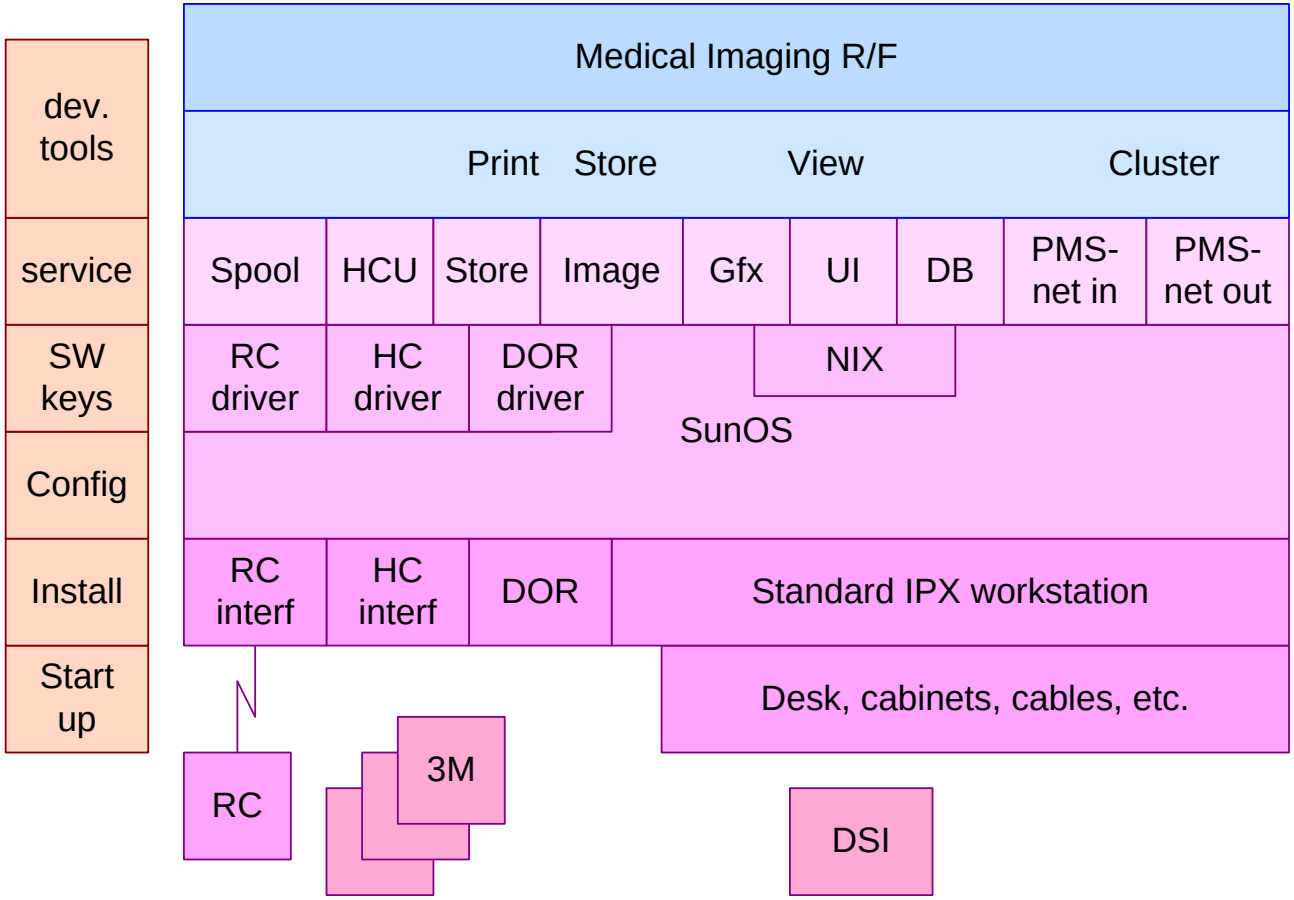


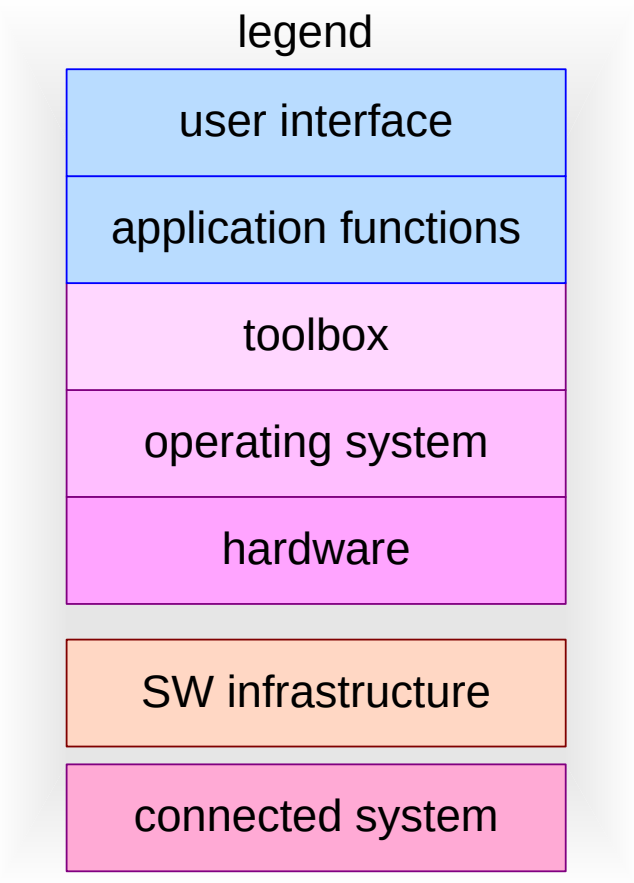
Criteria for Process Decomposition

Processes are a facility provided by the Operating System (OS) to manage concurrency, resources and exceptions

- 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 SW (Construction Decomposition)





Memory Use and Performance

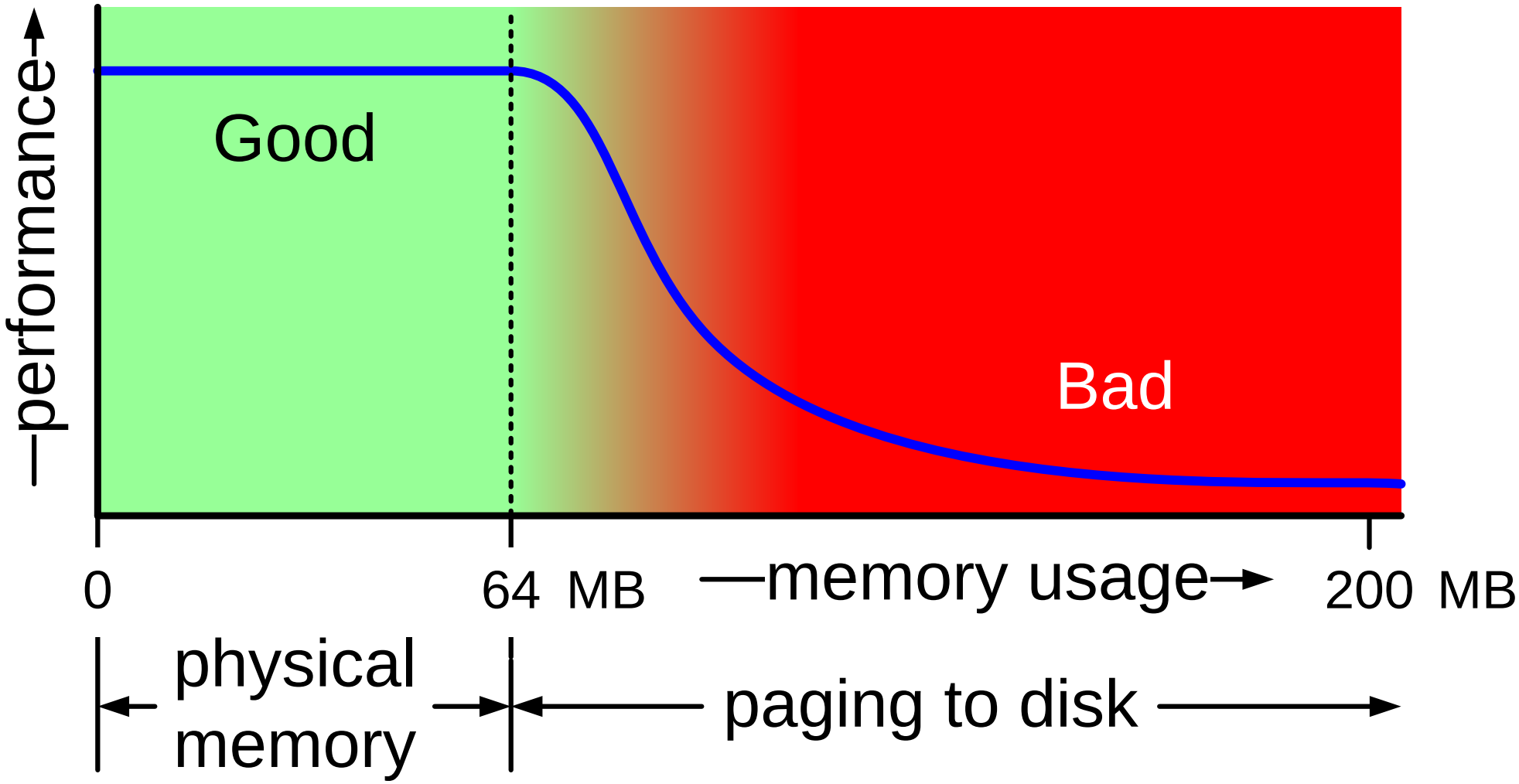
Easyvision Memory and Performance

Performance problems

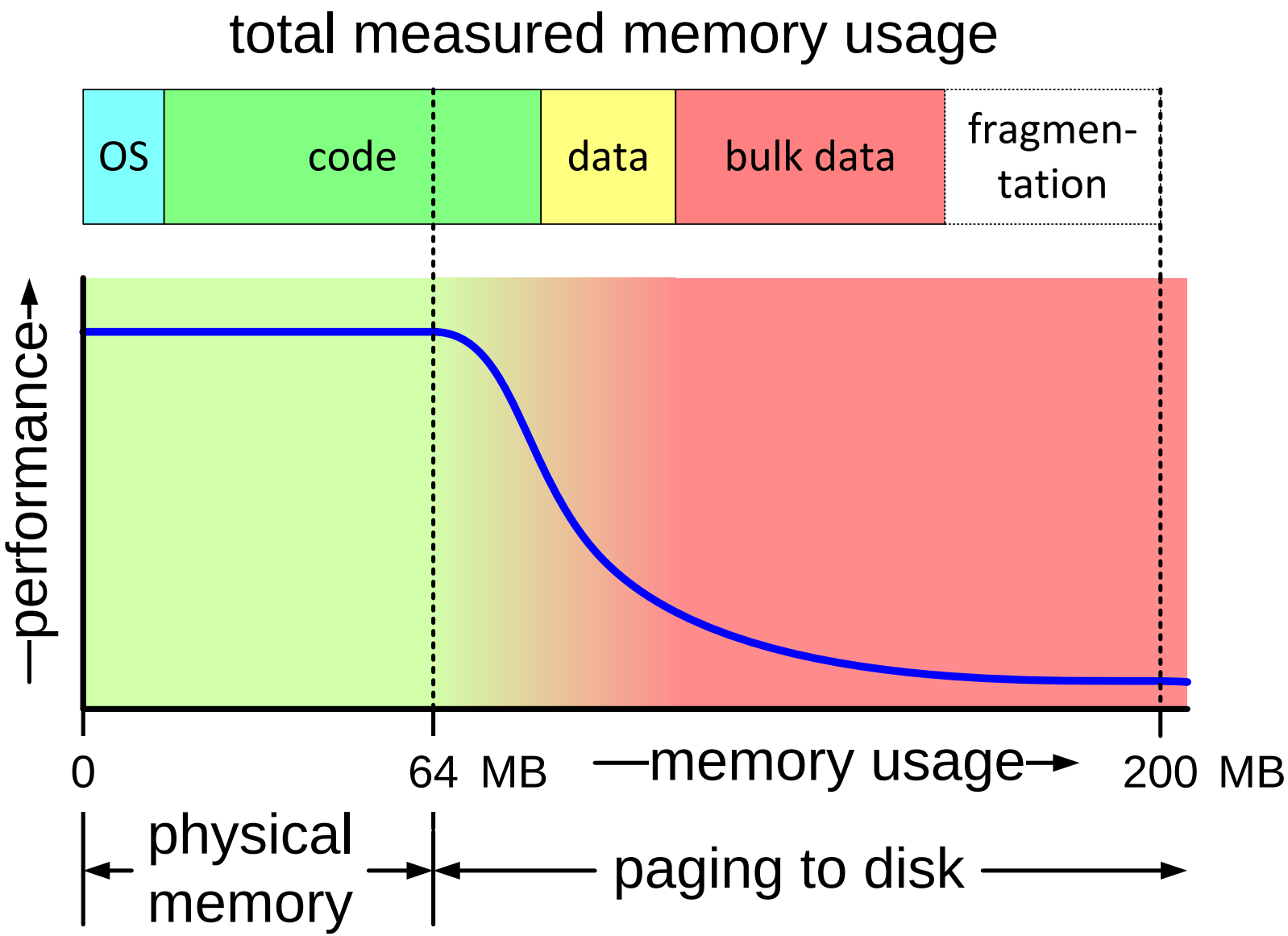
Analysis of memory use

Memory budget

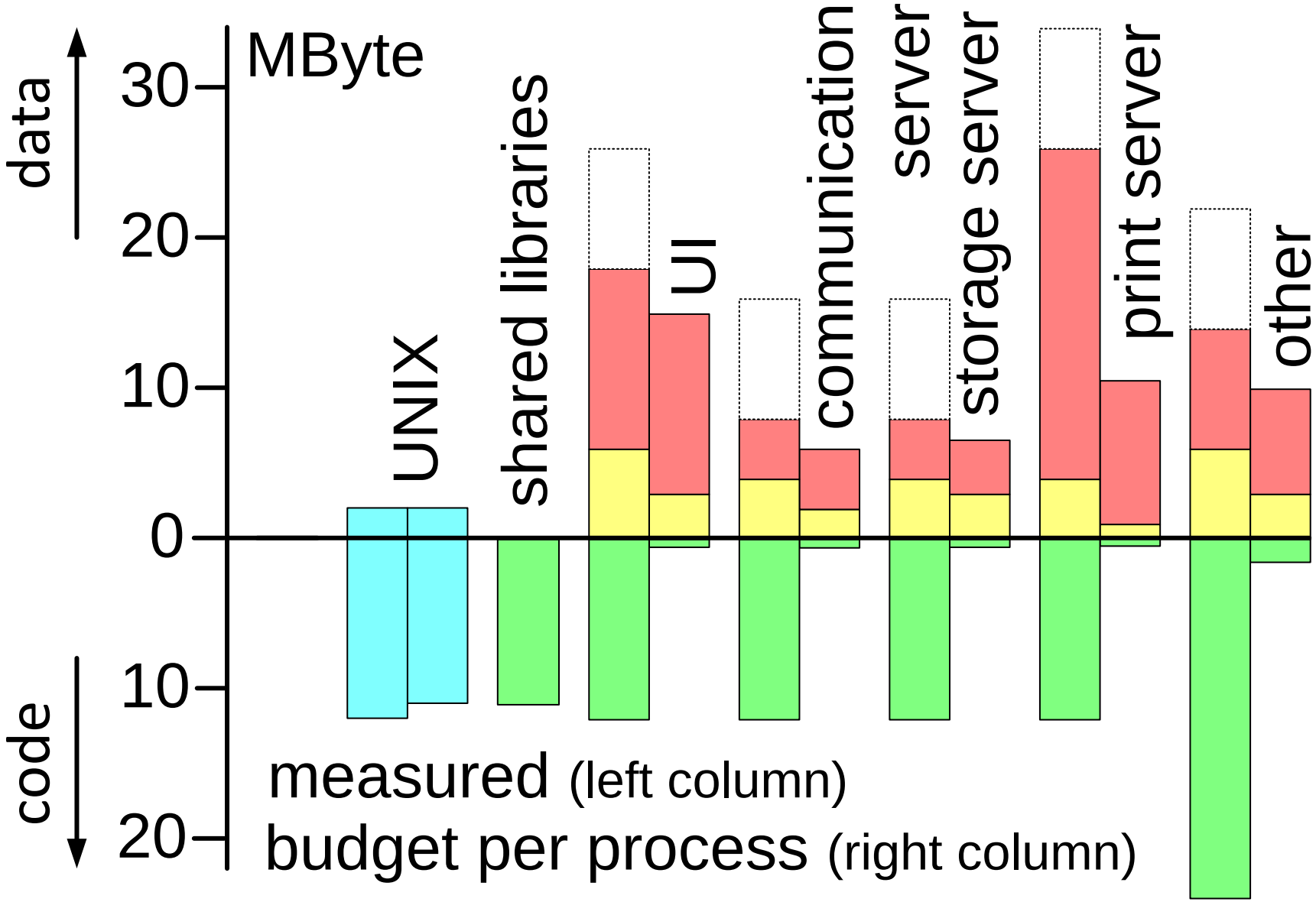
Performance as a Function of Memory Use



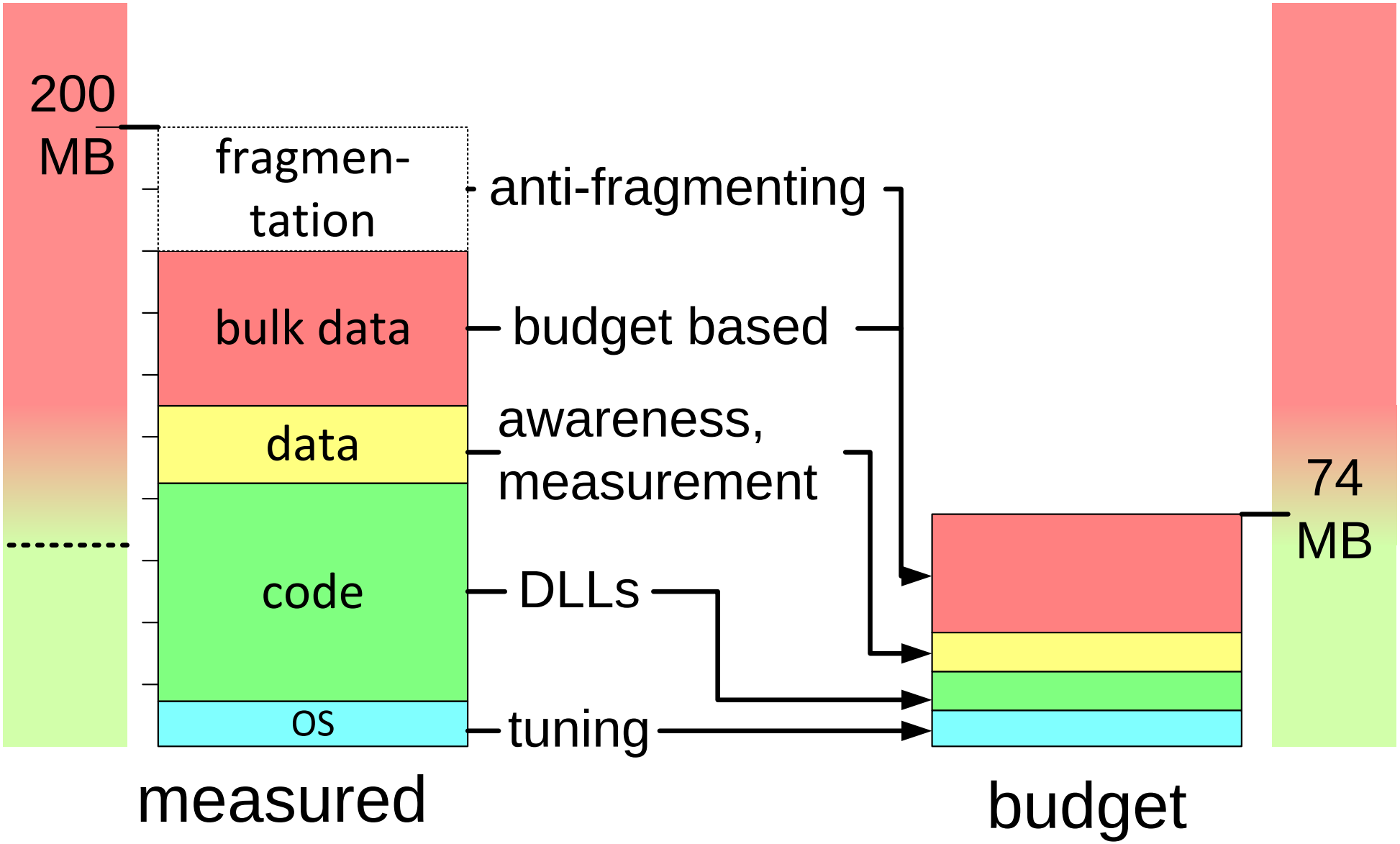
Problem: Unlimited Memory Consumption (1992)



Measurement Per Process



Solution: Measure and Iterative Redesign



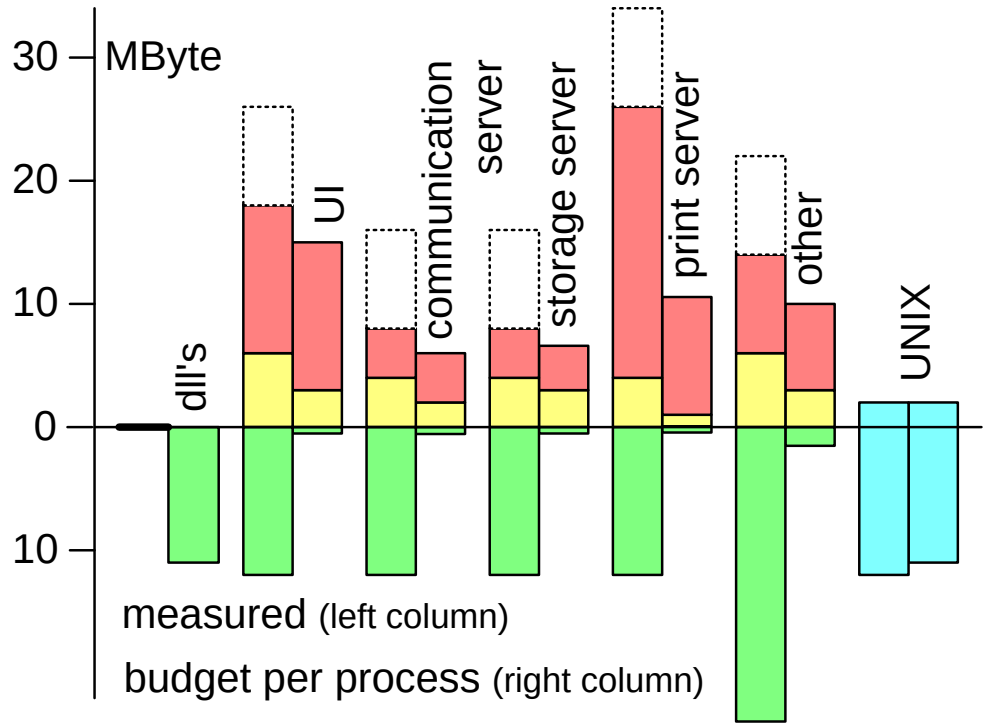
Method: Budget per Process

Budget:

+ measurable

+ fine enough to provide direction

+ coarse enough to be maintainable



Example of a Memory Budget

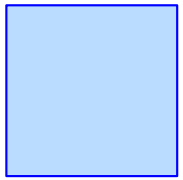
memory budget in Mbytes	code	obj data	bulk data	total
shared code	11.0			11.0
User Interface process	0.3	3.0	12.0	15.3
database server	0.3	3.2	3.0	6.5
print server	0.3	1.2	9.0	10.5
optical storage server	0.3	2.0	1.0	3.3
communication server	0.3	2.0	4.0	6.3
UNIX commands	0.3	0.2	0	0.5
compute server	0.3	0.5	6.0	6.8
system monitor	0.3	0.5	0	0.8
application SW total	13.4	12.6	35.0	61.0
UNIX Solaris 2.x				10.0
file cache				3.0
total				74.0

Exercise: Bulk Data Capacity

Memory block

12MByte

How many blocks of 1024 x 1024 8-bits data can be stored?



How many blocks of 1024 x 1024 16-bits data can be stored?

Exercise: Object Data Capacity

Object Data
3MByte

Frequency		Description		Typical size
1		Large objects (e.g. dictionary)		20 kB
20		Medium object, e.g. UI data		200 Bytes
1000		Small object, e.g. image attributes		20 Bytes
Total				

How many objects with this distribution fit in the 3MByte Object data store?

Memory Budget of Easyvision RF R1 and R2

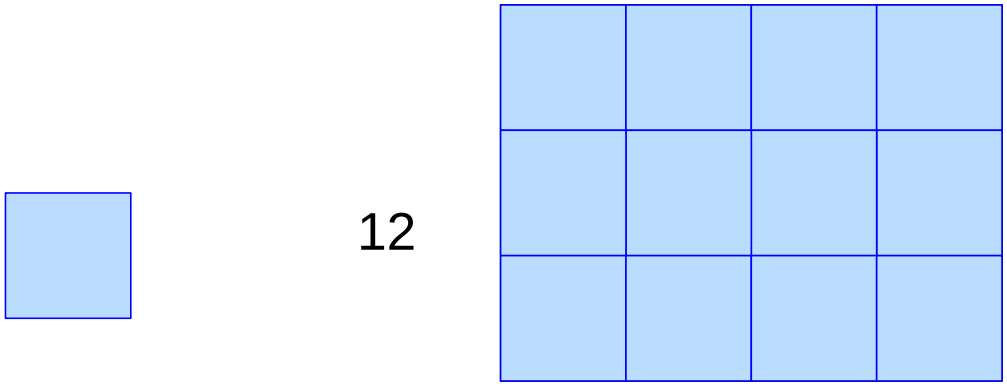
	code		object data		bulk data		total	
memory budget in Mbytes	R1	R2	R1	R2	R1	R2	R1	R2
shared code	6.0	11.0					6.0	11.0
UI process	0.2	0.3	2.0	3.0	12.0	12.0	14.2	15.3
database server	0.2	0.3	4.2	3.2		3.0	4.4	6.5
print server	0.4	0.3	2.2	1.2	7.0	9.0	9.6	10.5
DOR server	0.4	0.3	4.2	2.0	2.0	1.0	6.6	3.3
communication 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

Answer: Bulk Data Capacity

Memory block

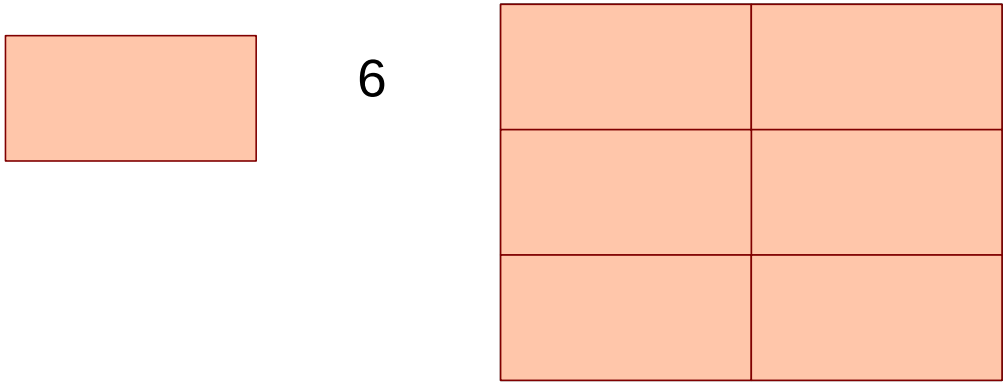
12MByte

How many blocks of 1024 x 1024 8-bits data can be stored?



12

How many blocks of 1024 x 1024 16-bits data can be stored?



6

* Assuming that 8-bit data is stored as 8-bit (char)
  Assuming that 16-bit data is stored as 16-bit (short int)

Answer: Object Data Capacity

Object Data
3MByte

Frequency		Description		Typical size		Size * Freq
1		Large objects (e.g. dictionary)		20 kB		20 kB
20		Medium object, e.g. UI data		200 Bytes		4kB
1000		Small object, e.g. image attributes		20 Bytes		20kB
Total						44kB

44kByte fits approximately 68 times in 3MByte
Expect to store at most 68 large objects
(1360 Medium sized objects, 68000 small objects)

Memory Use and Performance

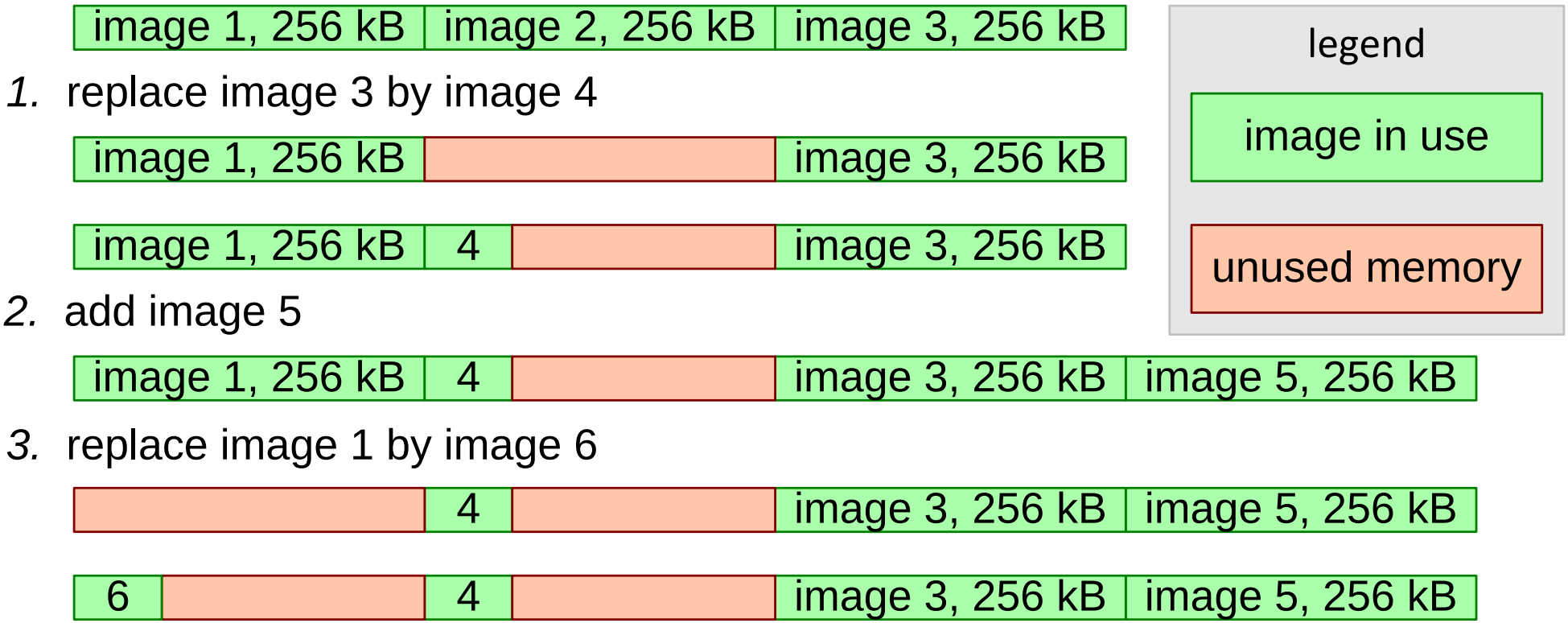
Easyvision Memory Design

Fragmentation and consequences

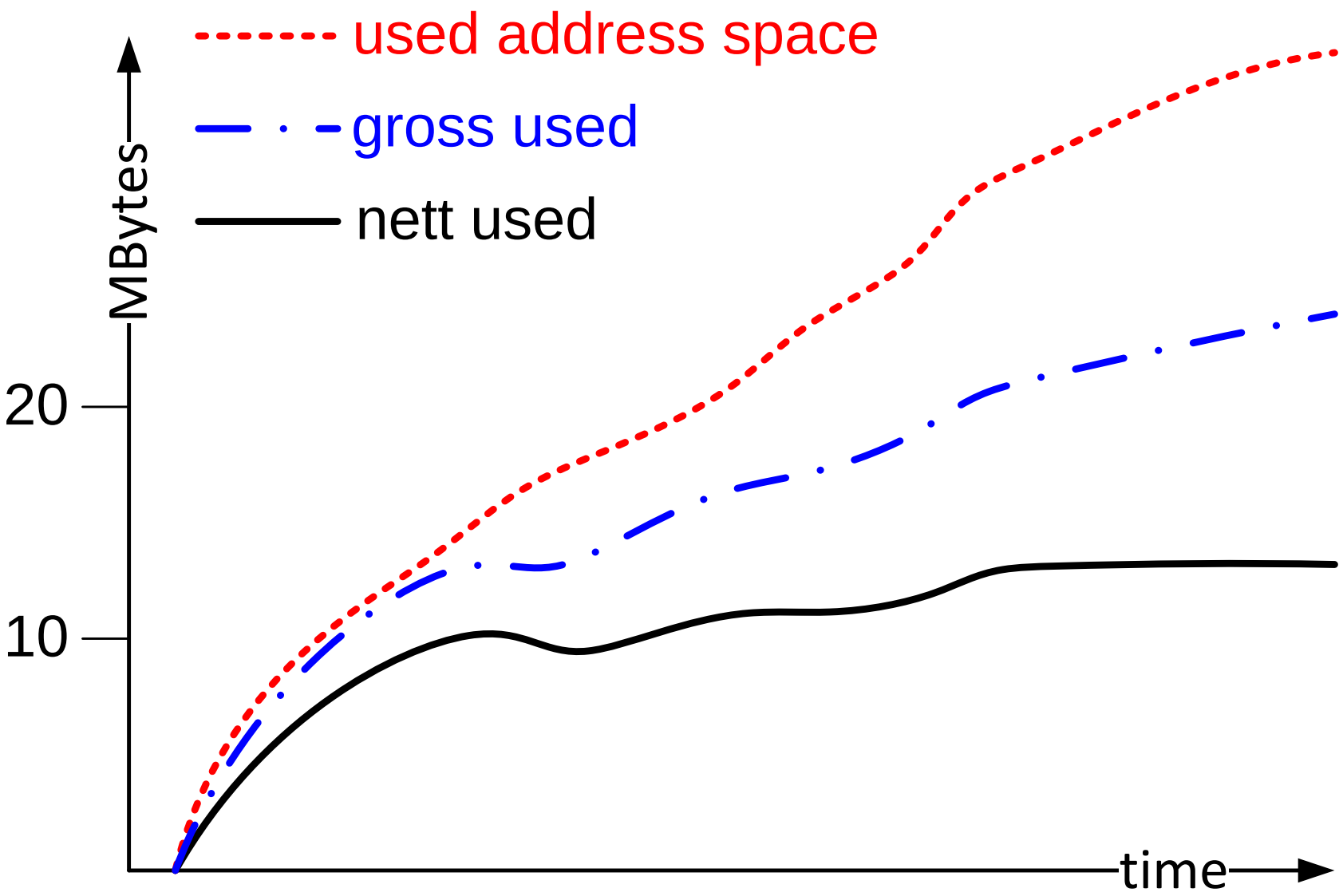
Application caches

Memory design applied

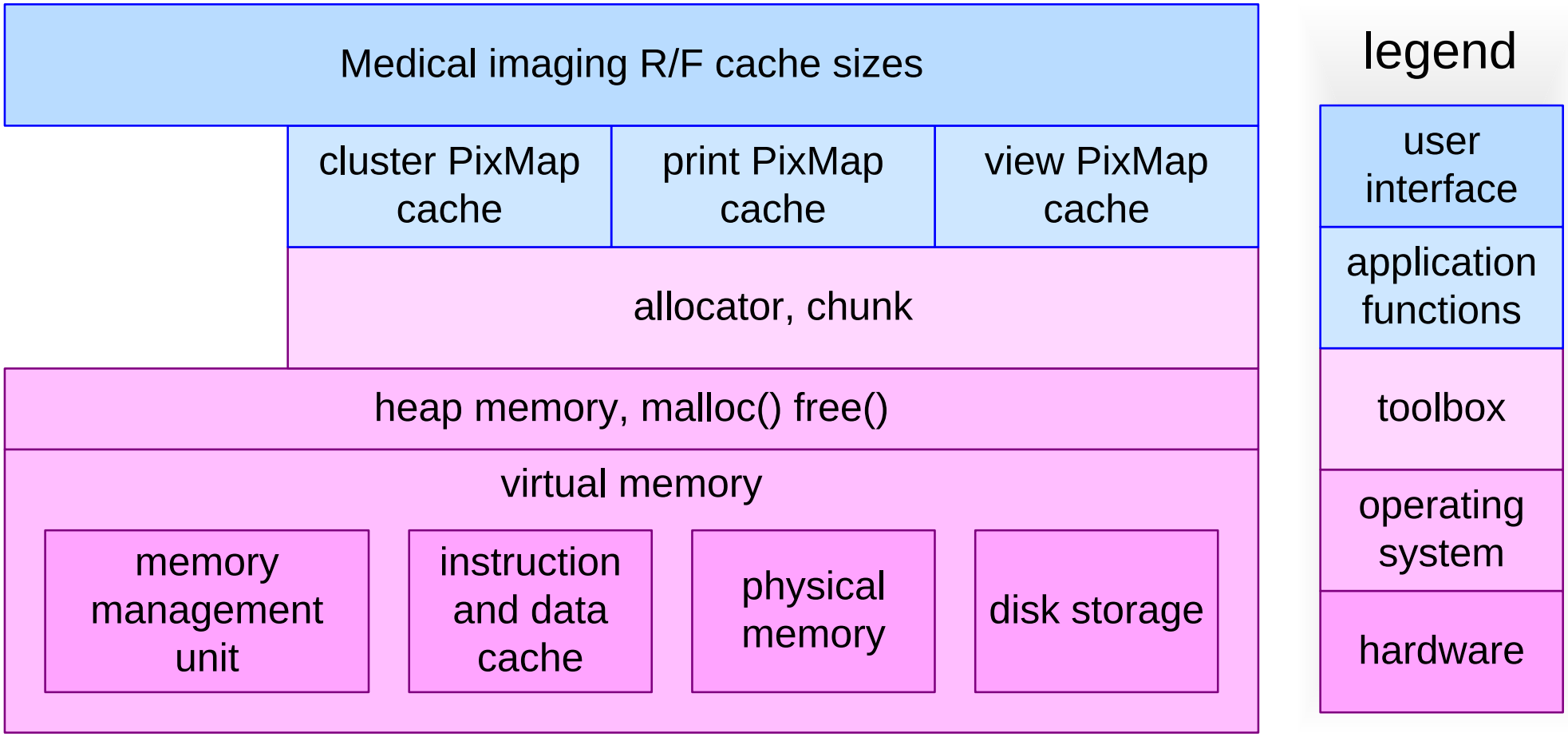
Memory Fragmentation



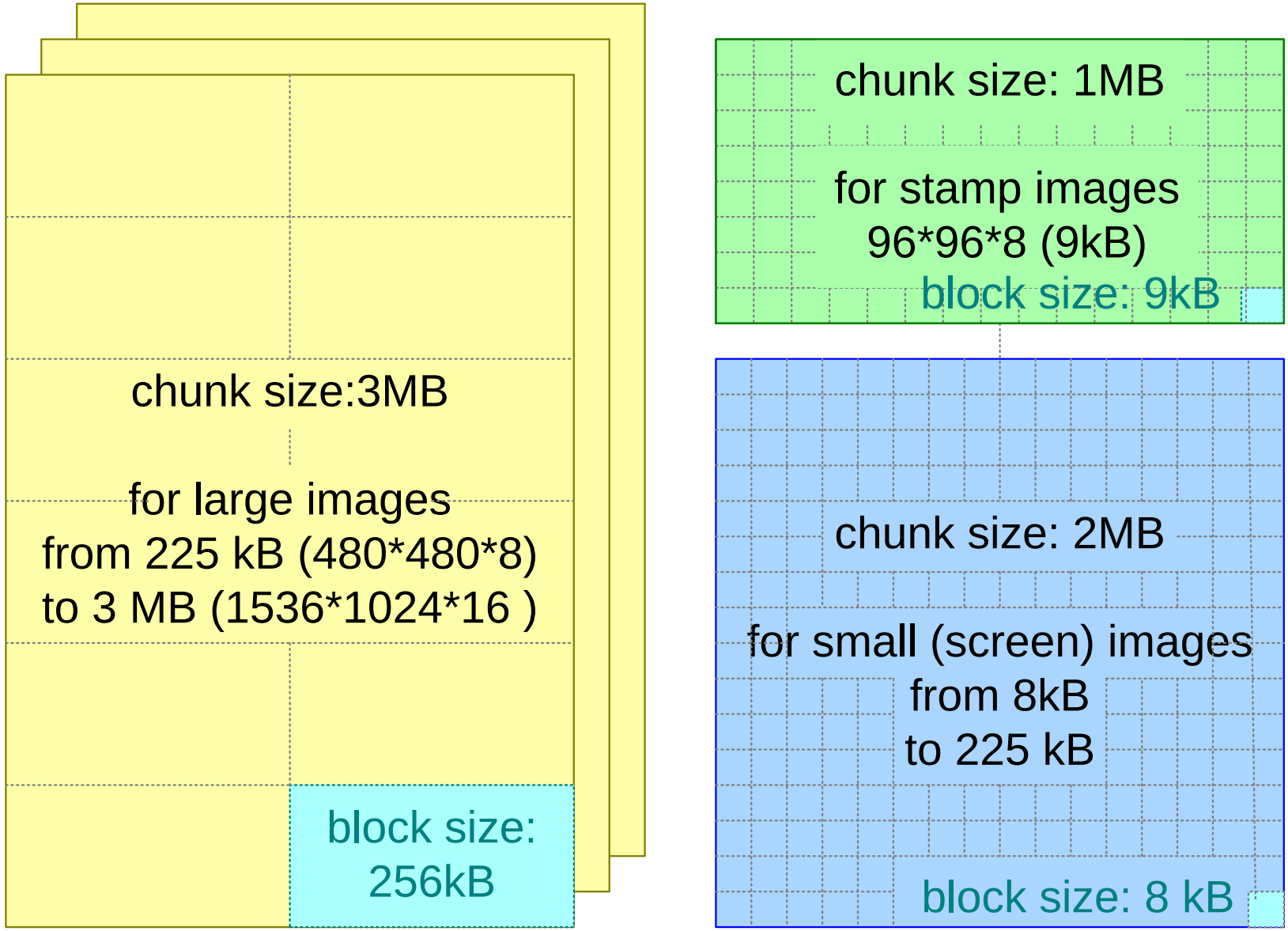
Memory Fragmentation Increase



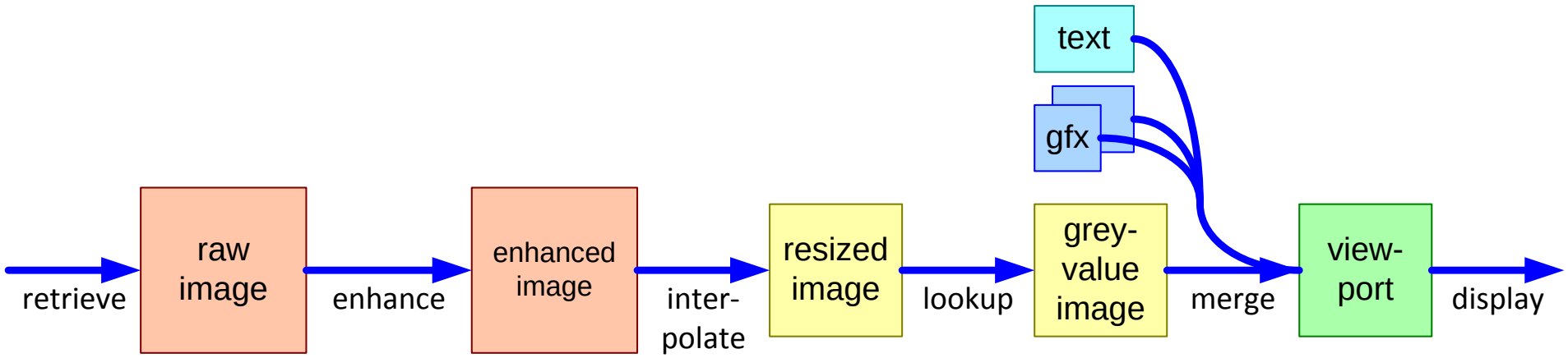
Cache Layers



Bulk Data Memory Management Memory Allocators



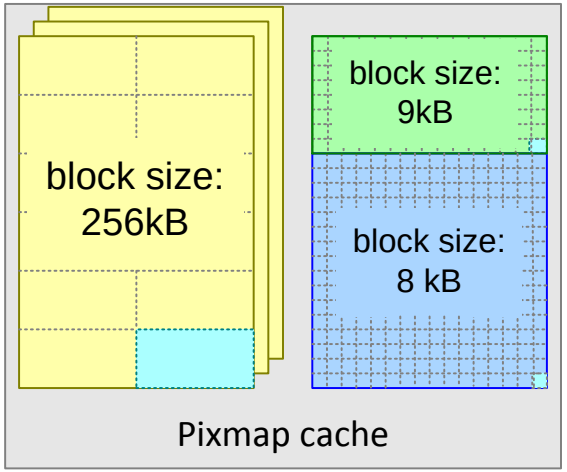
Cached Intermediate Processing Results



Example of Allocator and Cache Use

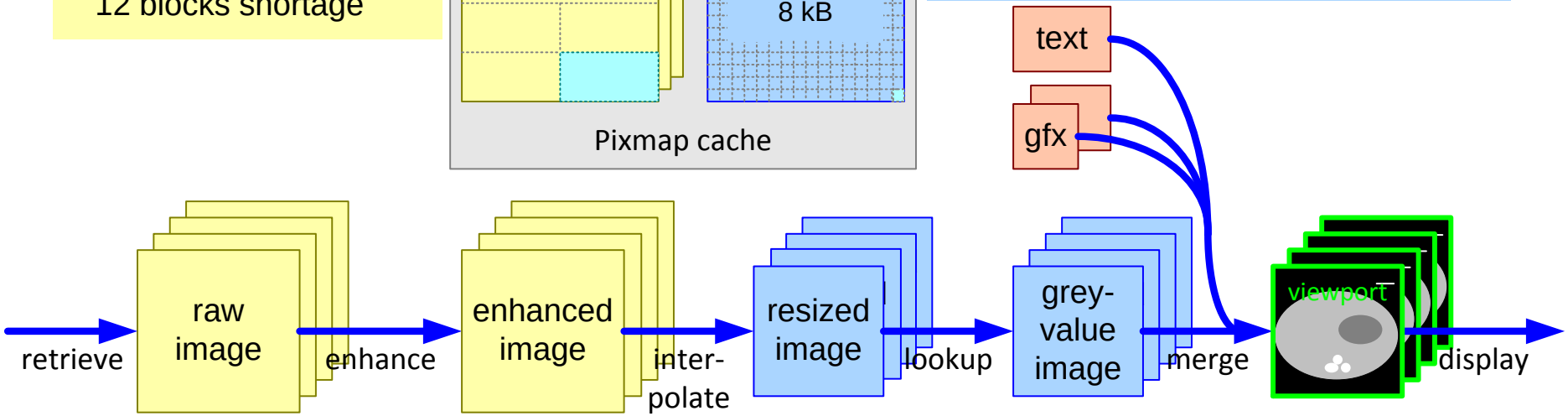
1024^2 8 bit image requires
4 256kB blocks

8 1024^2 images require
48 256kB blocks
12 blocks shortage



460^2 image 8 bit requires 27 8kB blocks
200^2 images require 5 8kb blocks

all screen-size images require
334 8kB blocks, 78 blocks shortage



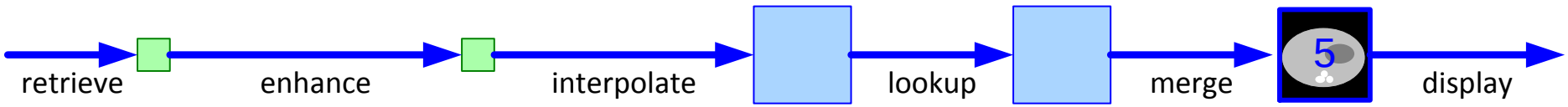
$4 * 1024^2$
1 byte / pixel

$4 * 1024^2$
2 byte / pixel

$4 * 460^2$
2 byte / pixel

$4 * 460^2$
1 byte / pixel

$4 * 460^2$
1 byte / pixel



96^2

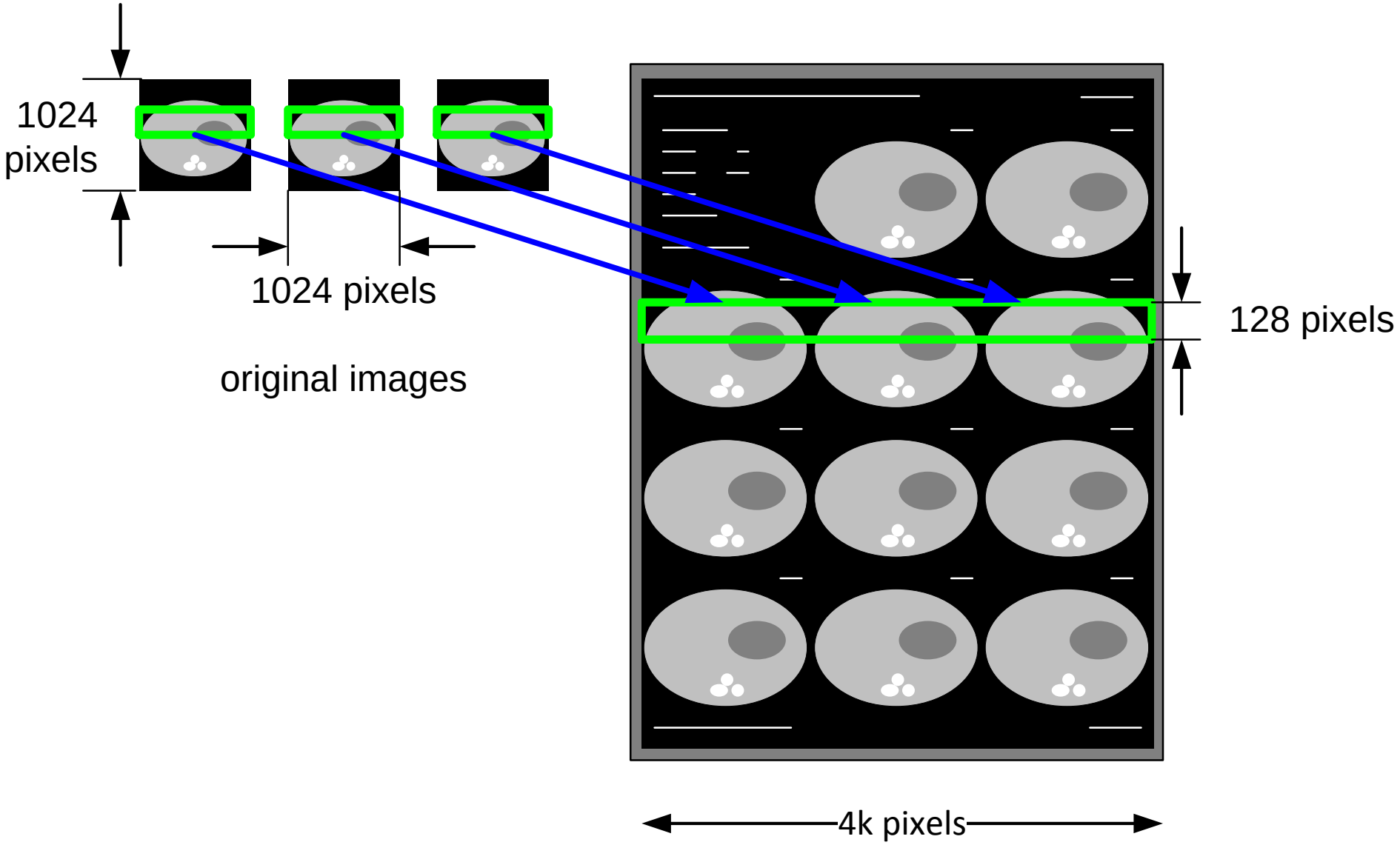
96^2

200^2

200^2

200^2

Print Server is Based on Banding



CPU Load and Performance

Easyvision Memory CPU load and performance

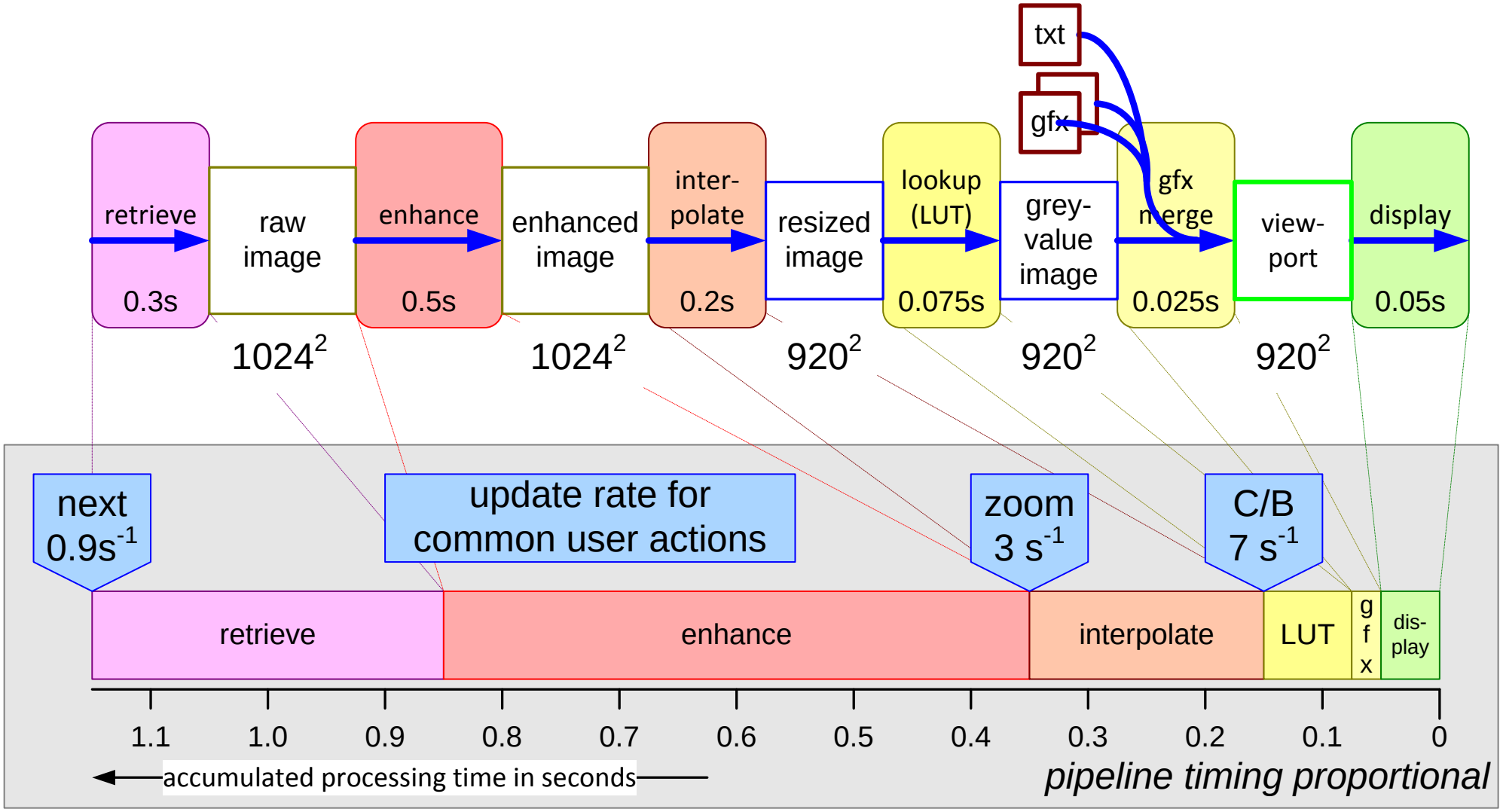
CPU load analysis

response time

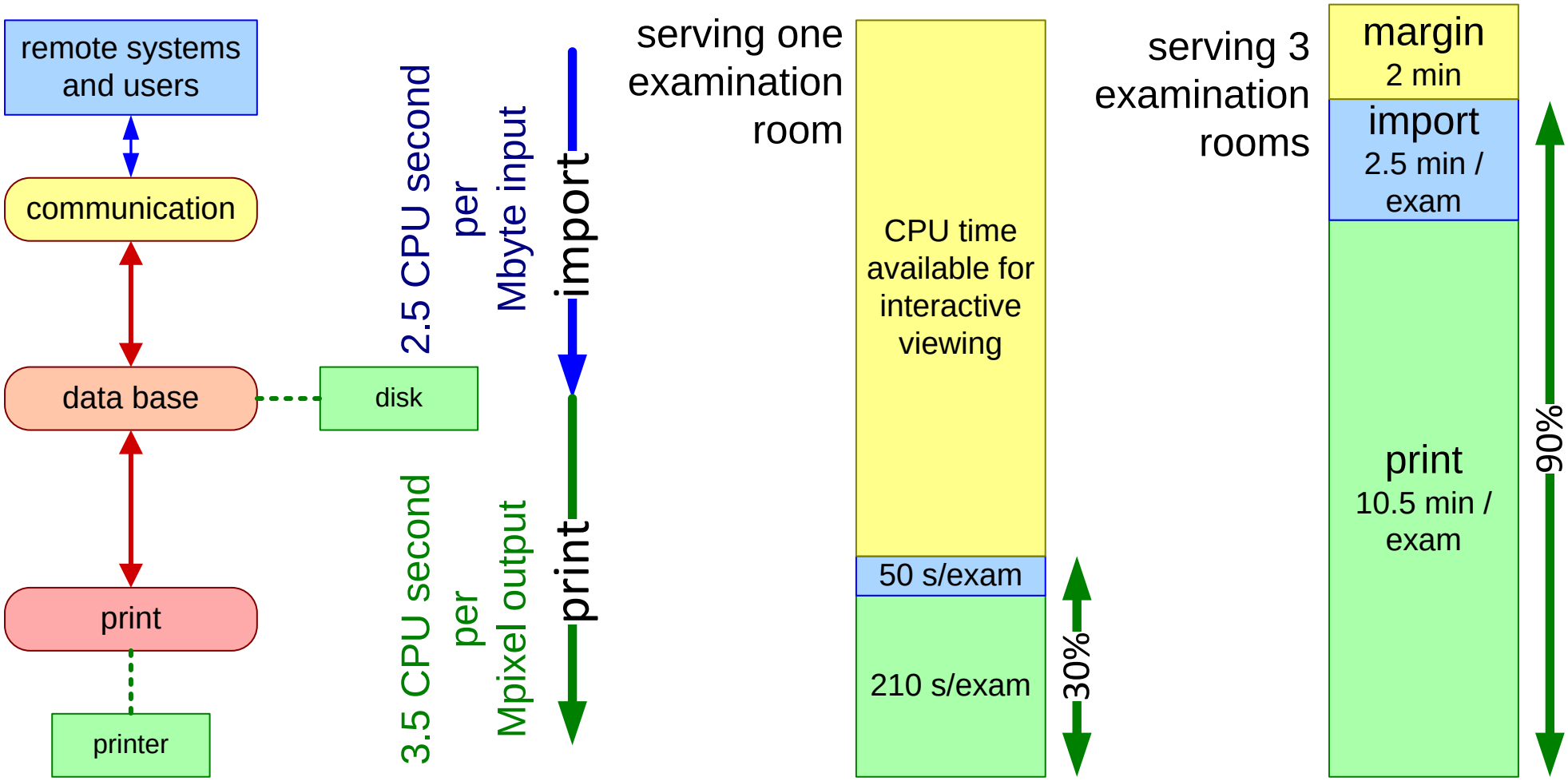
throughput

measurement tools

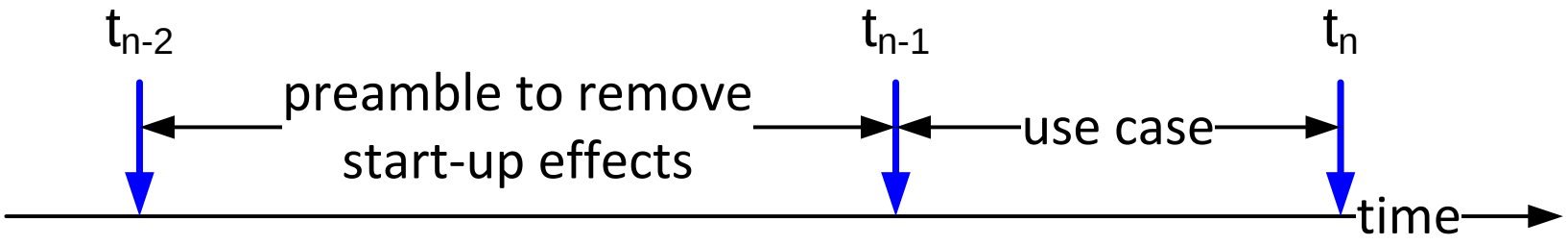
CPU Processing Times and Viewing Responsiveness



Server CPU Load



Resource Measurement Tools



oit	△ object instantations 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
public	SpecInt (by suppliers)	CPU integer	coarse	new hardware
	Byte benchmark	computer platform performance OS, shell, file I/O	coarse	new hardware new OS release
self made	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

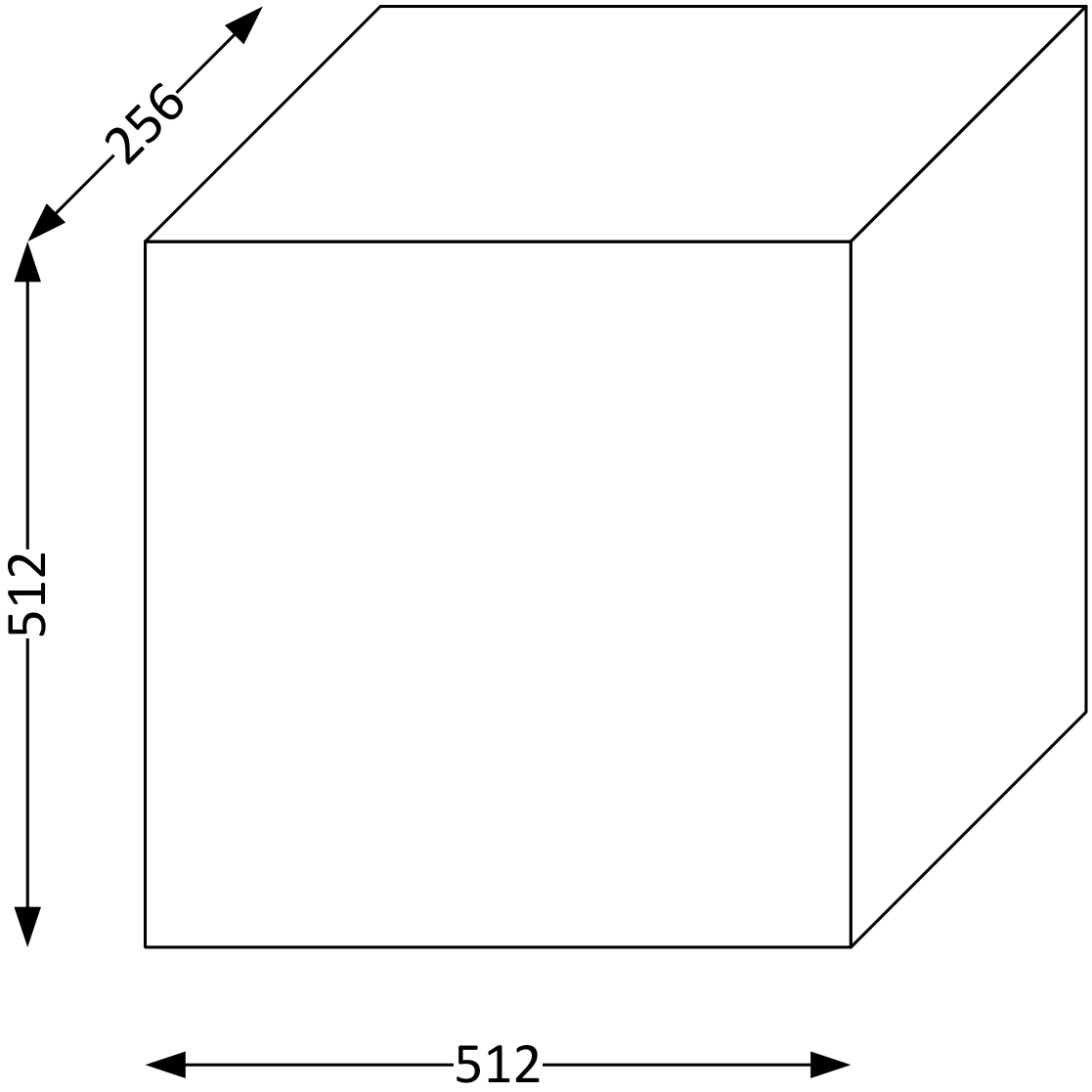
Case 4

MRI Volume Reconstruction and Viewing

Usage patterns as impact on performance

Resource model and requirements identification for usage patterns

Volume Acquisition and Reconstruction



Data in bytes =

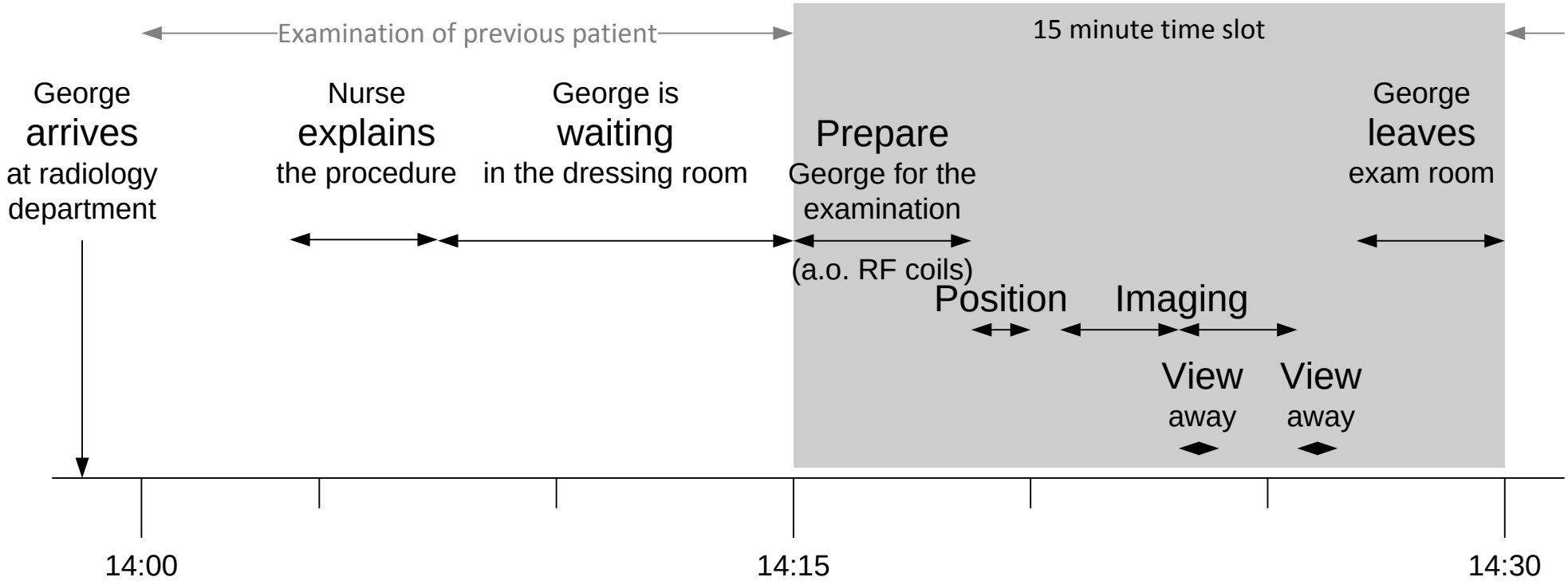
2 * 512 * 512 * 256 * 2 =

Volumes x y z bytes per pixel

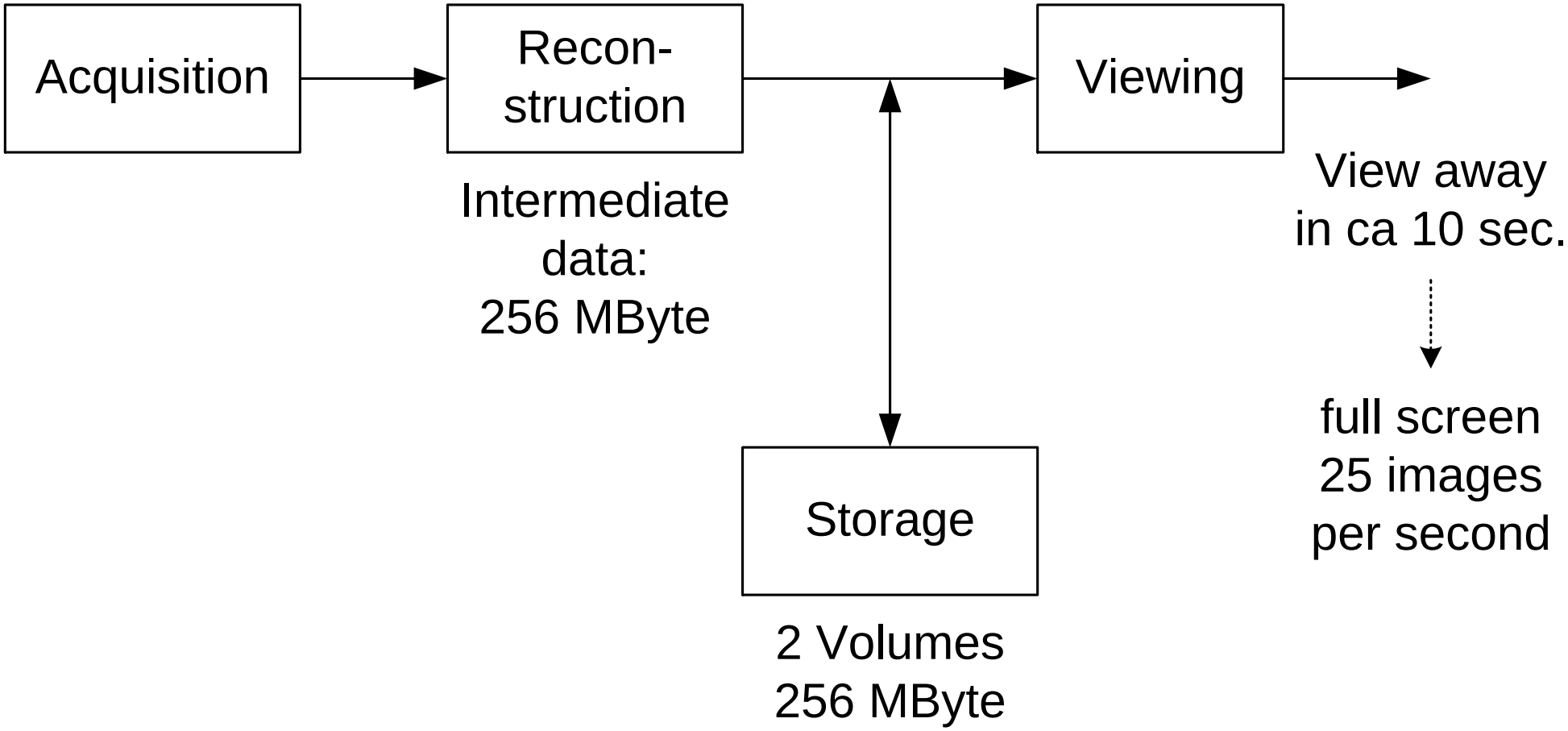
256 MBytes

in 2 * 2 minutes =
240 seconds

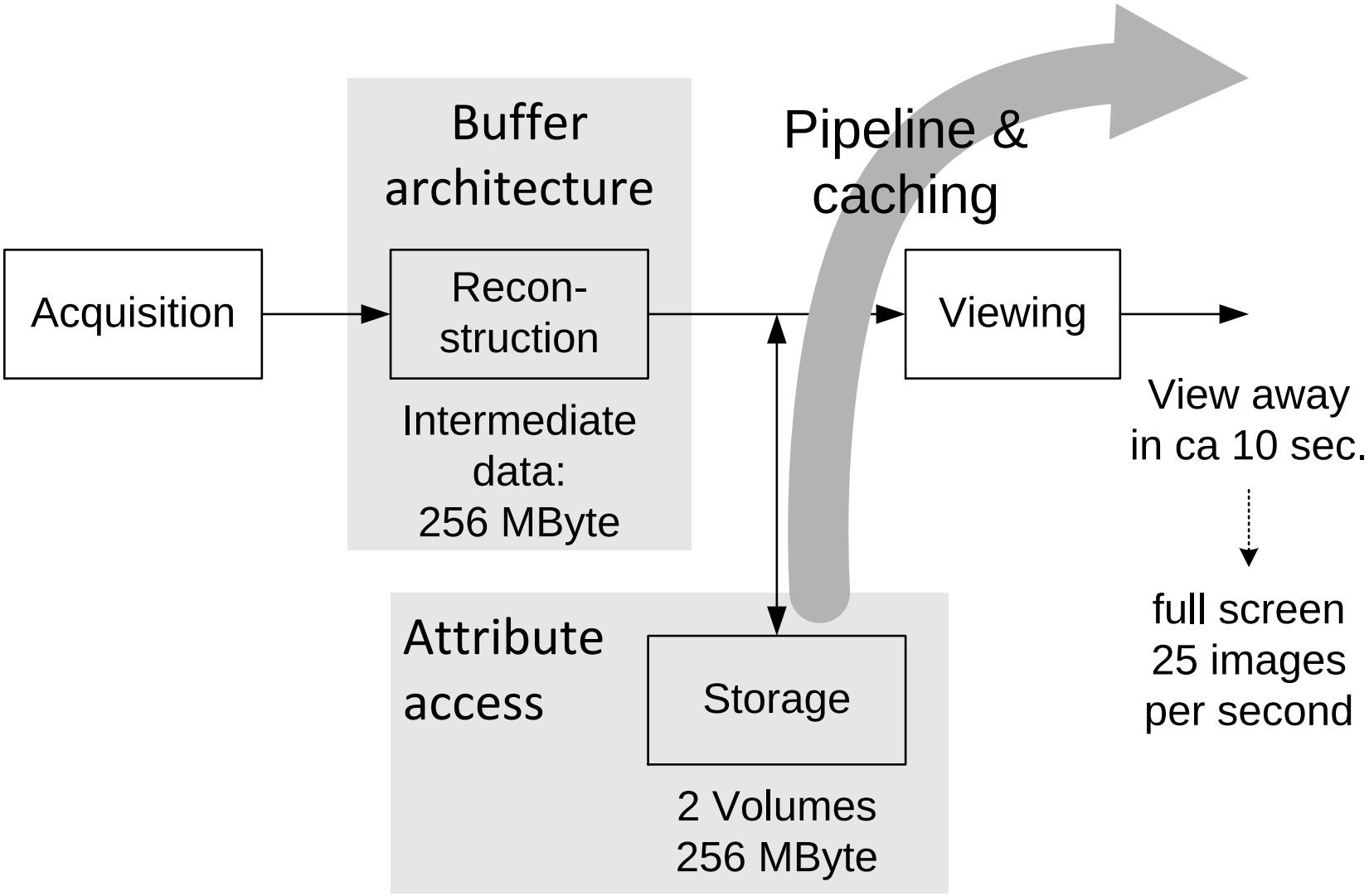
Performance Requirements



Resource Model



Critical Resources



Case 4

MRI Volume Reconstruction and Viewing

Operational usage pattern drives (implicit/explicit) system performance requirements

Resource / cost trade-off must support operational usage patterns

Case 5

Mobile Display Appliances

Modelling external environment

End-to-end performance

Allocation choices

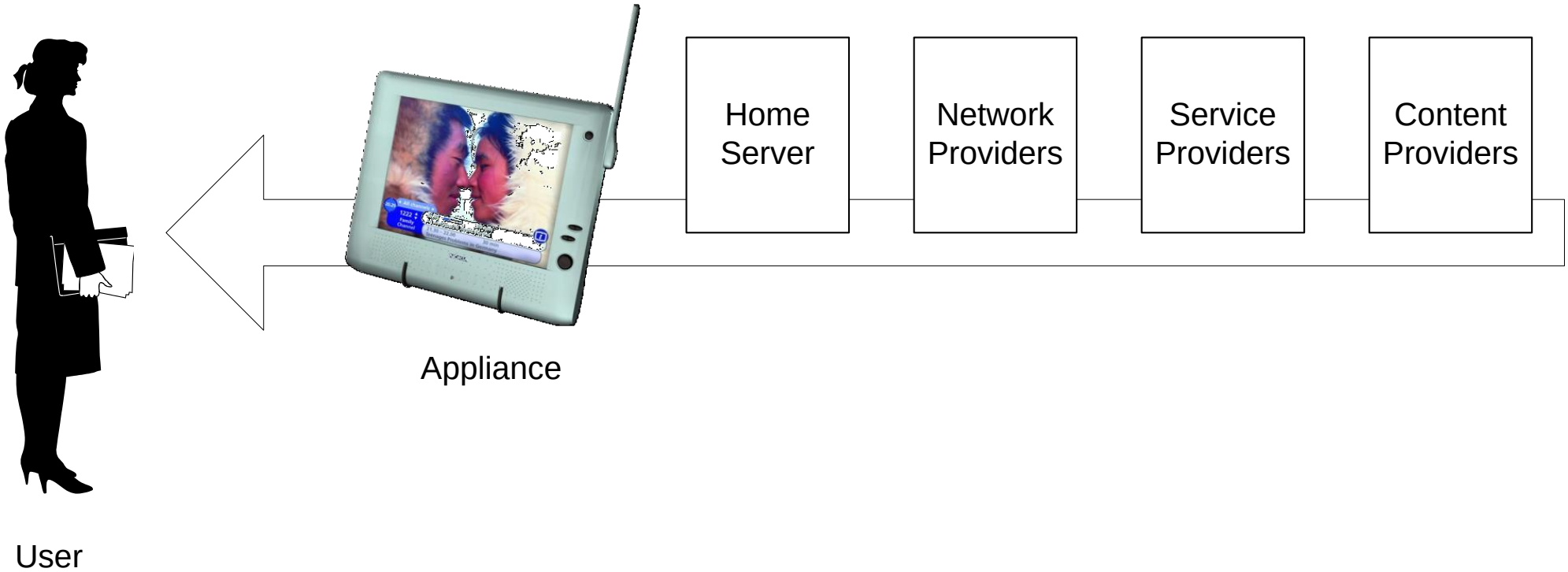
Mobile Display Appliances

Mobile Display Appliance

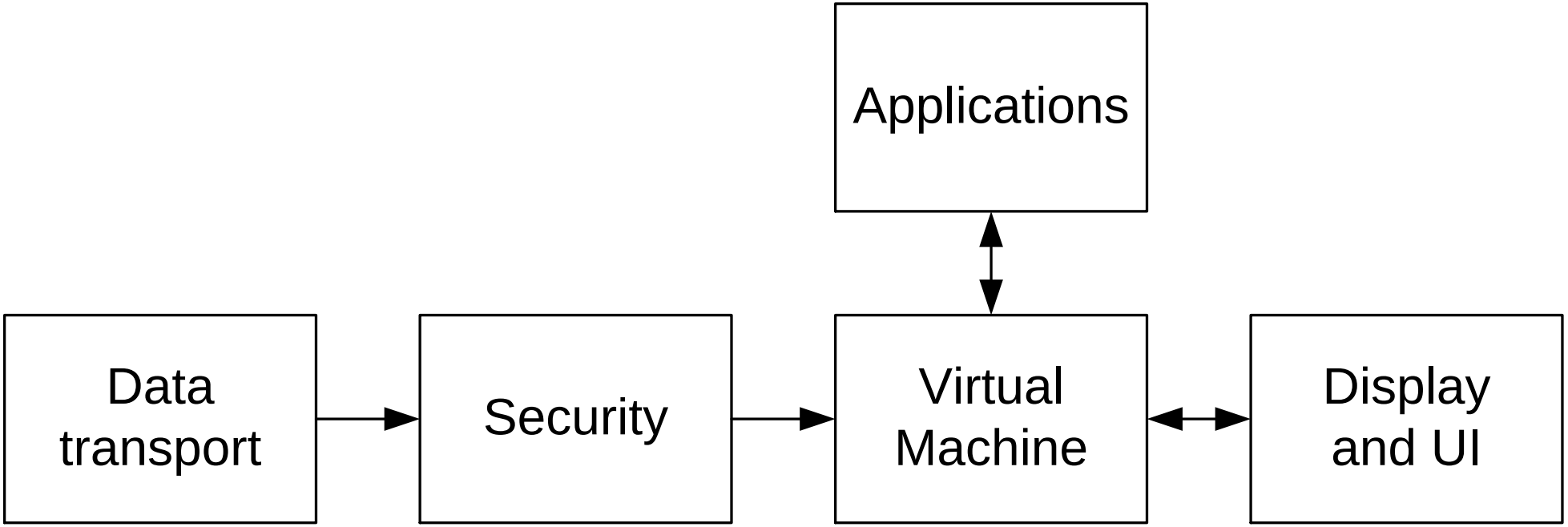
Mediascreen

Original pictures from Nokia

User Access Point to a Long Foodchain

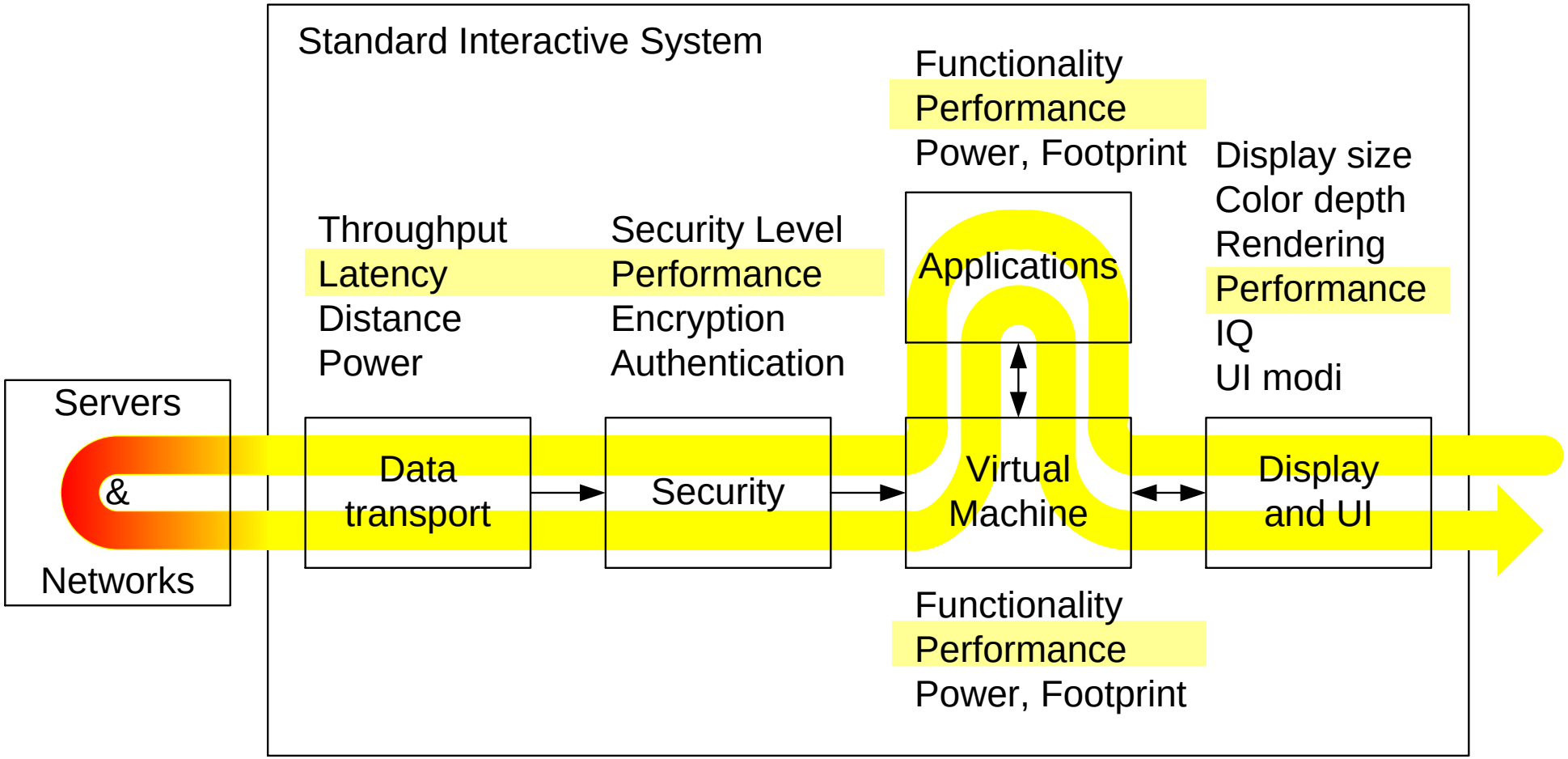


Standard Interactive System



free after Nick Thorne, Philips Semiconductors,
Systems Laboratory Southampton UK,
as presented at PSAVAT April 2001

Specifiable Characteristics

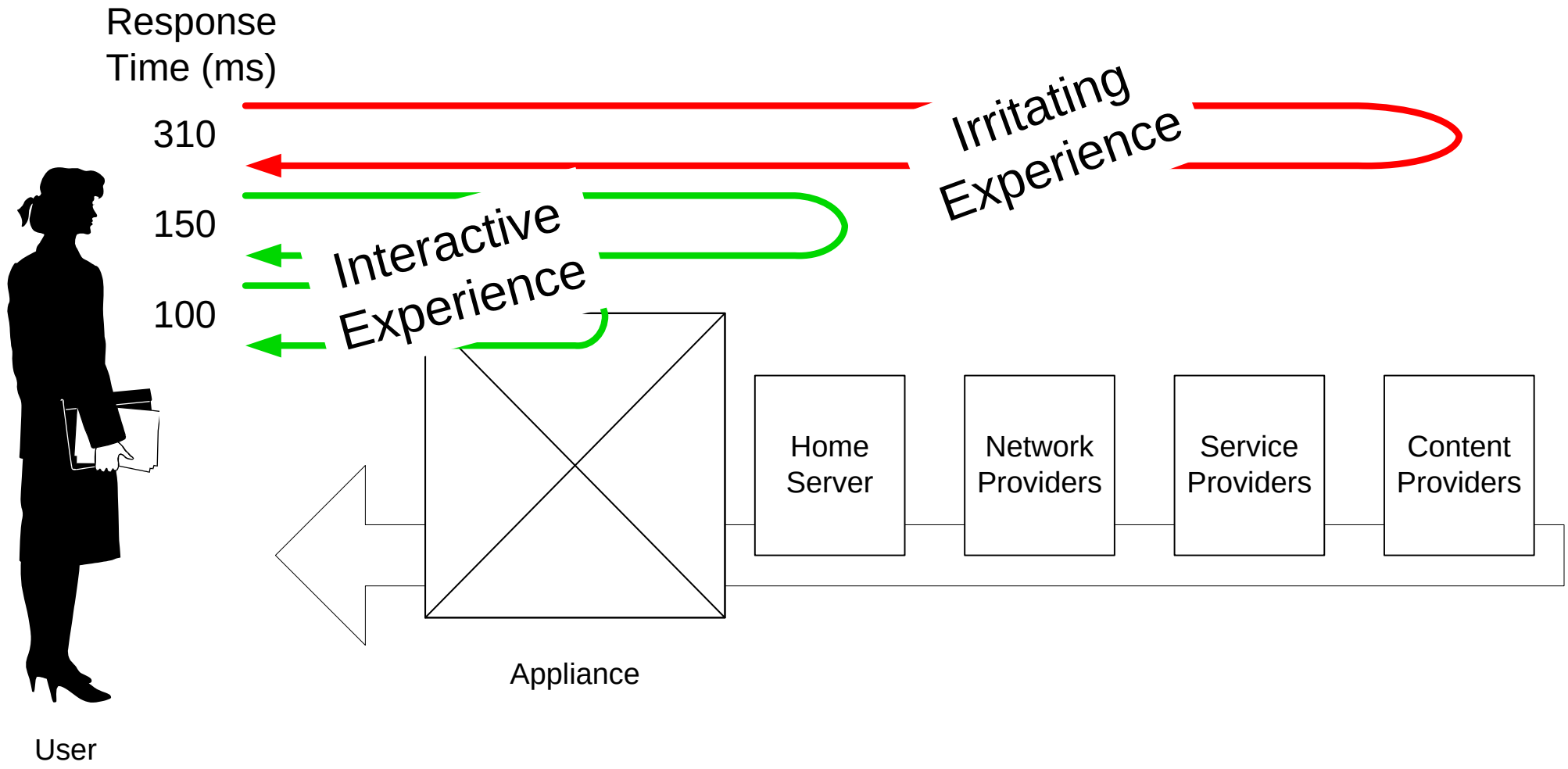


Response Time: Latency Budget

times in milliseconds	Message Latency		Response Time	
Appliance		40		100
Data transport	10		20	
Security	10		20	
Virtual Machine	10		20	
Application	10		30	
Graphics and UI	0		10	
Home Network		20		50
Home Server	10		30	
Network contention	10		20	
Provider Infrastructure		50		160
Last-Mile network	10		20	
Backbone network	20		40	
Service server	10		50	
Content server	10		50	
Total		110		310
User need				200

All numbers are imaginary and for illustration purposes only

Interaction or Irritation?



Case 5 Summary

Mobile Display Appliances

Modelling external environment: make assumptions

End-to-end performance:

large part of performance budget is not controlled

User perceived performance determines function allocation

Colofon

The ASP™ course is partially derived from the EXARCH course developed at *Philips CTT* by *Ton Kostelijk* and *Gerrit Muller*.

Extensions and additional slides have been developed at *ESI* by *Teun Hendriks*, *Roland Mathijssen* and *Gerrit Muller*.