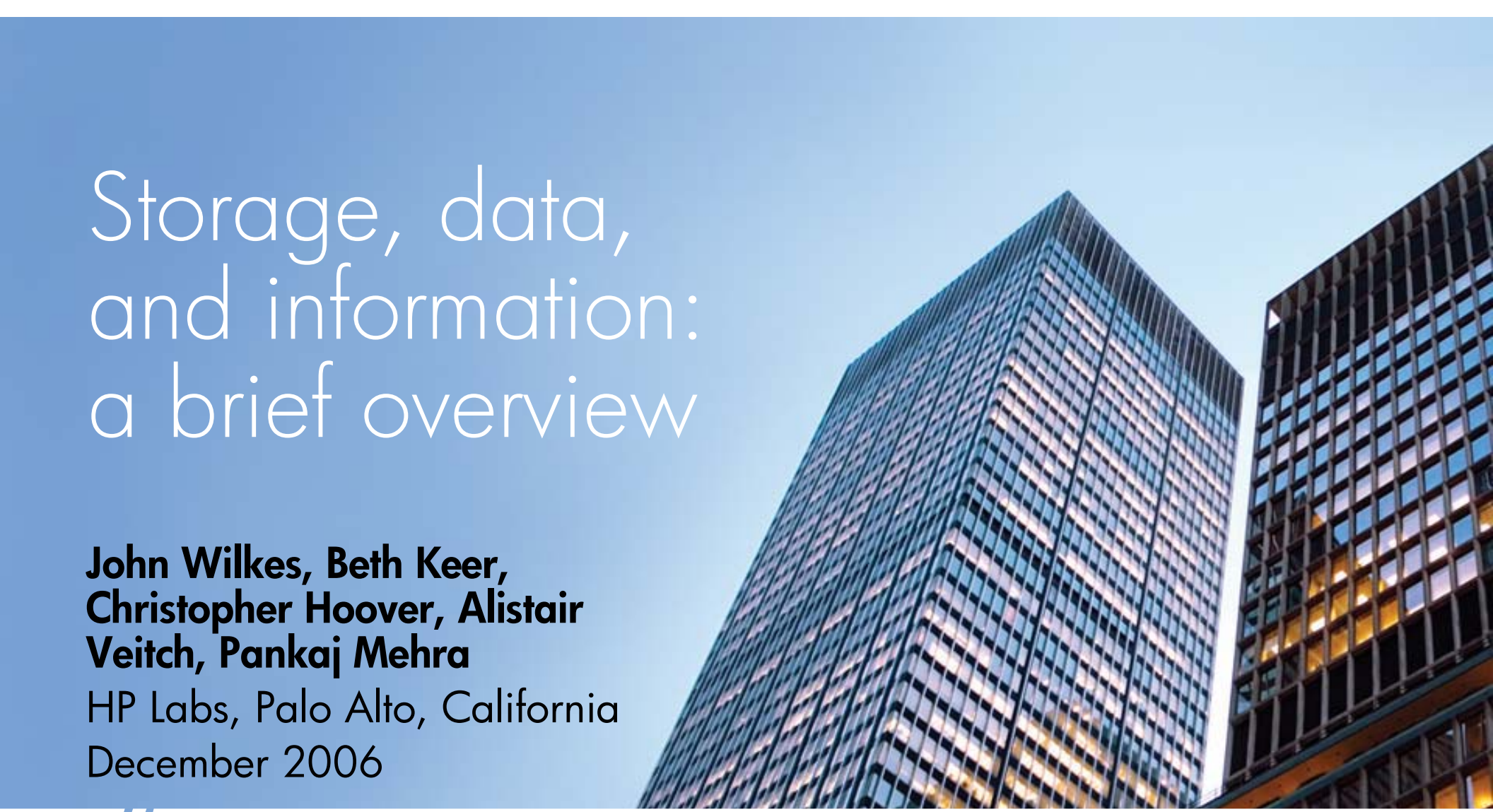
Storage, data, and information: a brief overview

John Wilkes, Beth Keer, Christopher Hoover, Alistair Veitch, Pankaj Mehra
HP Labs, Palo Alto, California
December 2006



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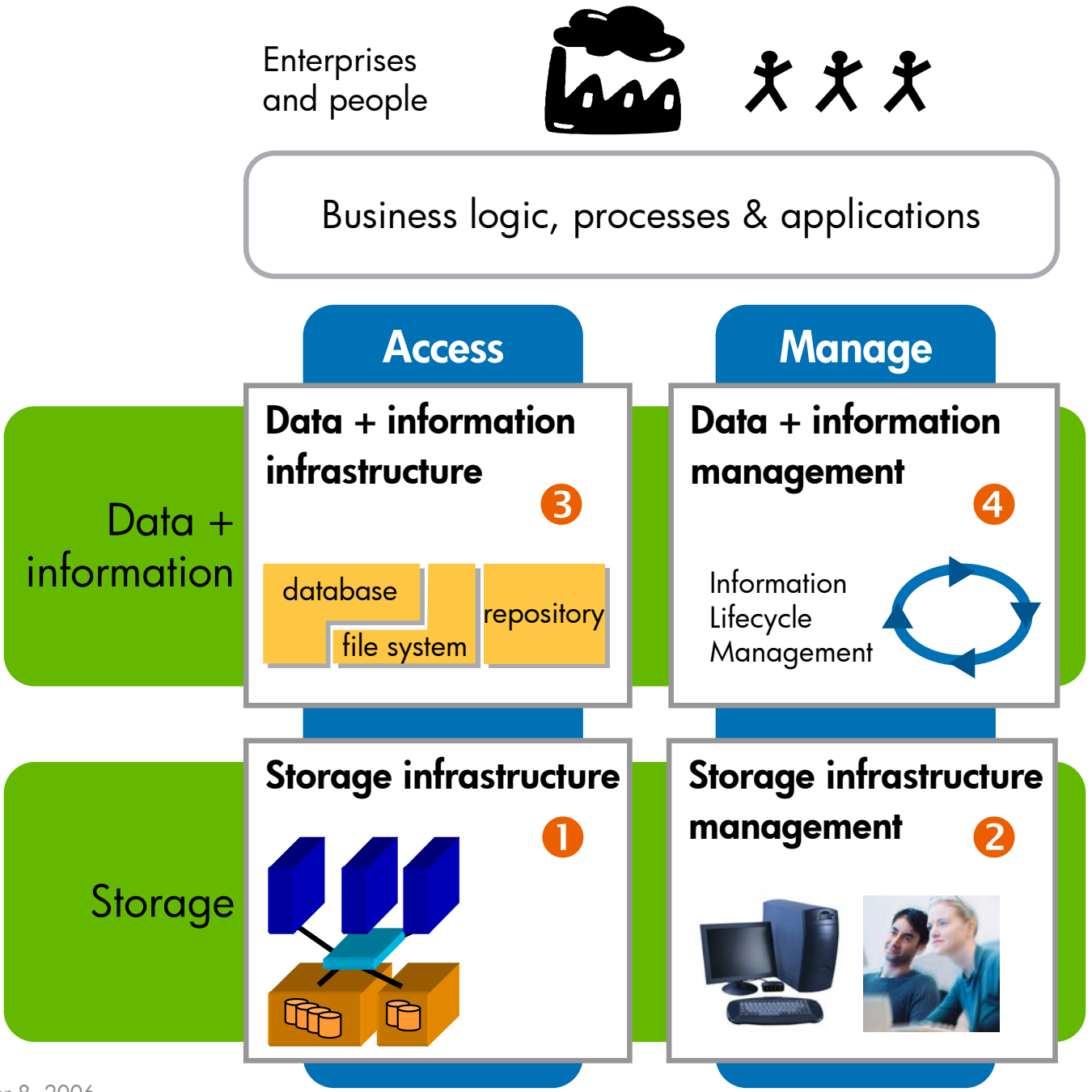
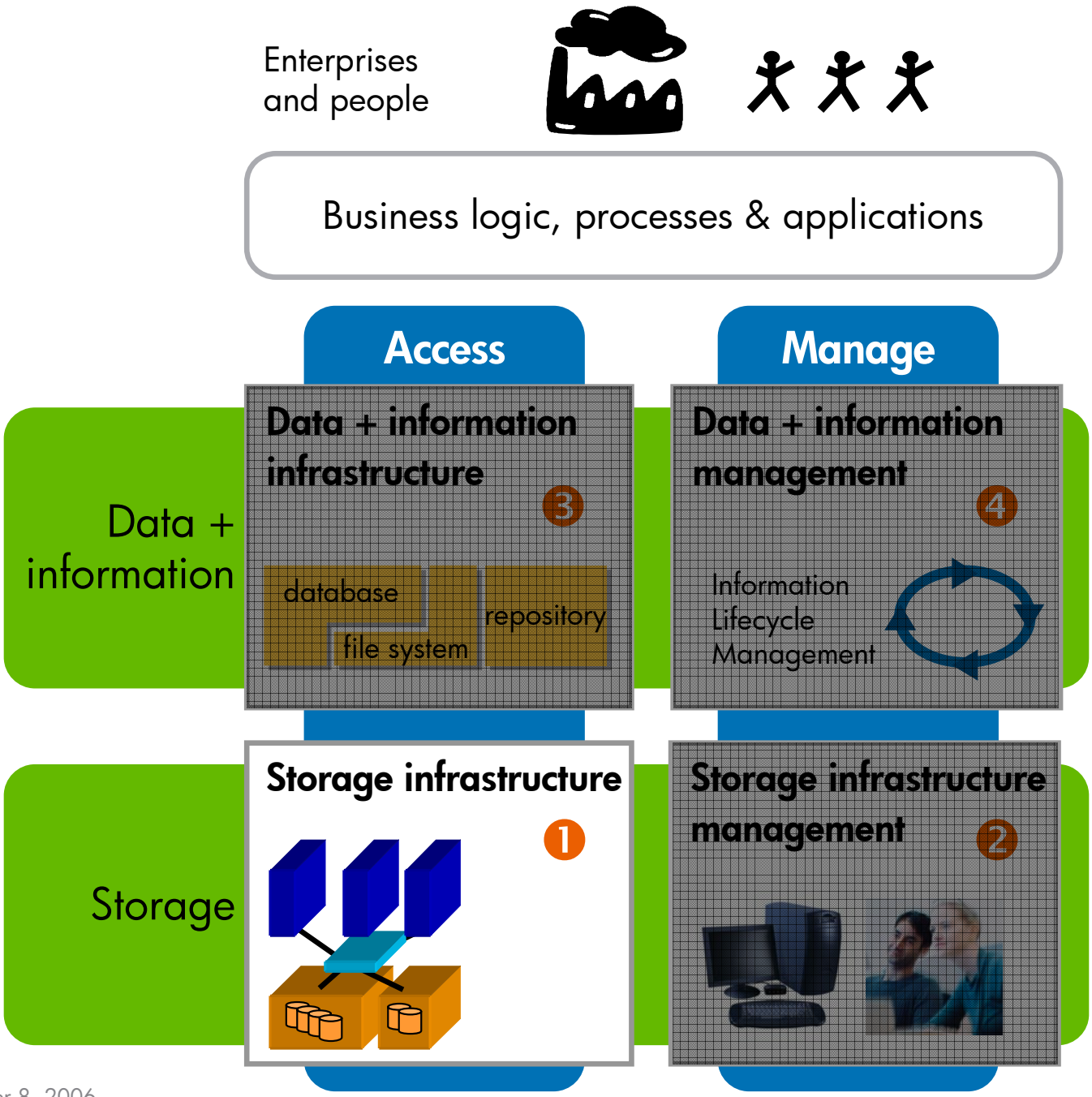
Roadmap

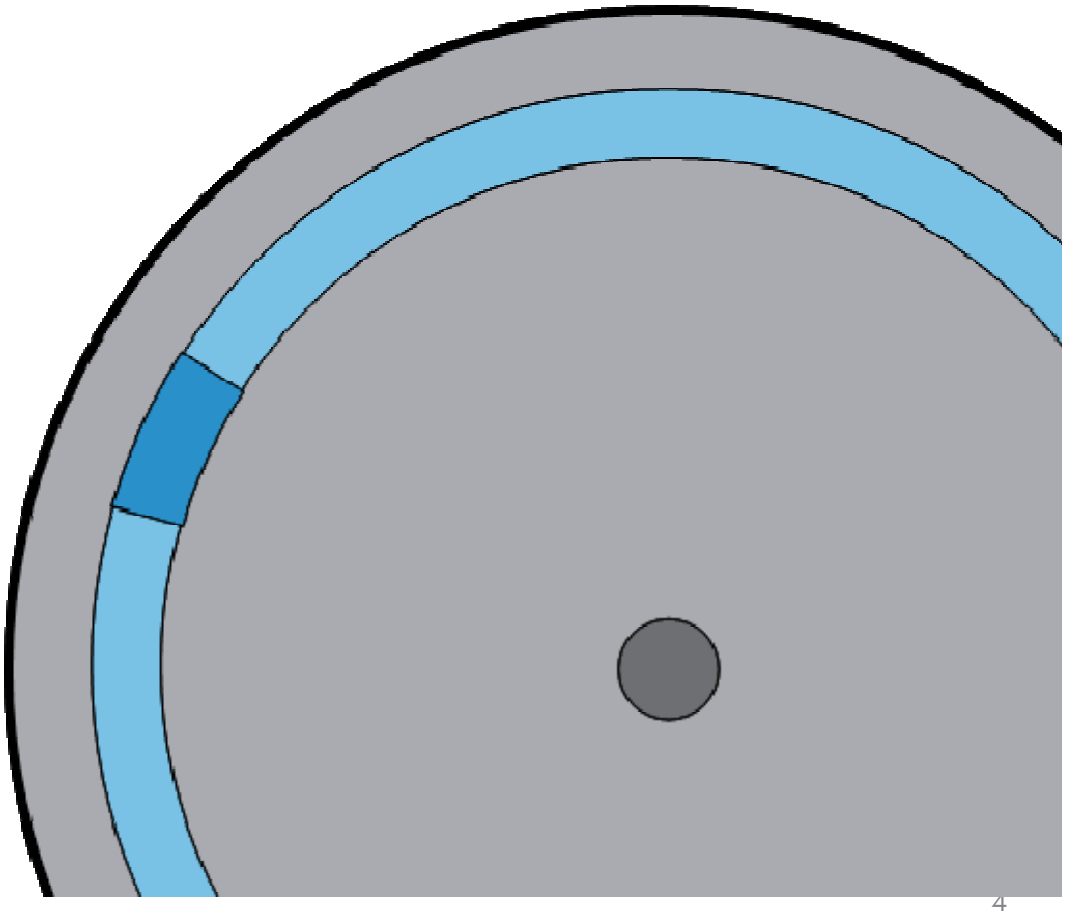

Enterprises and people
Business logic, processes & applications
Access
Manage
Data + information
Storage
Data + information infrastructure
3
database
file system
repository
Data + information management
4
Information Lifecycle Management
Storage infrastructure
1
Storage infrastructure management
2

Storage infrastructure

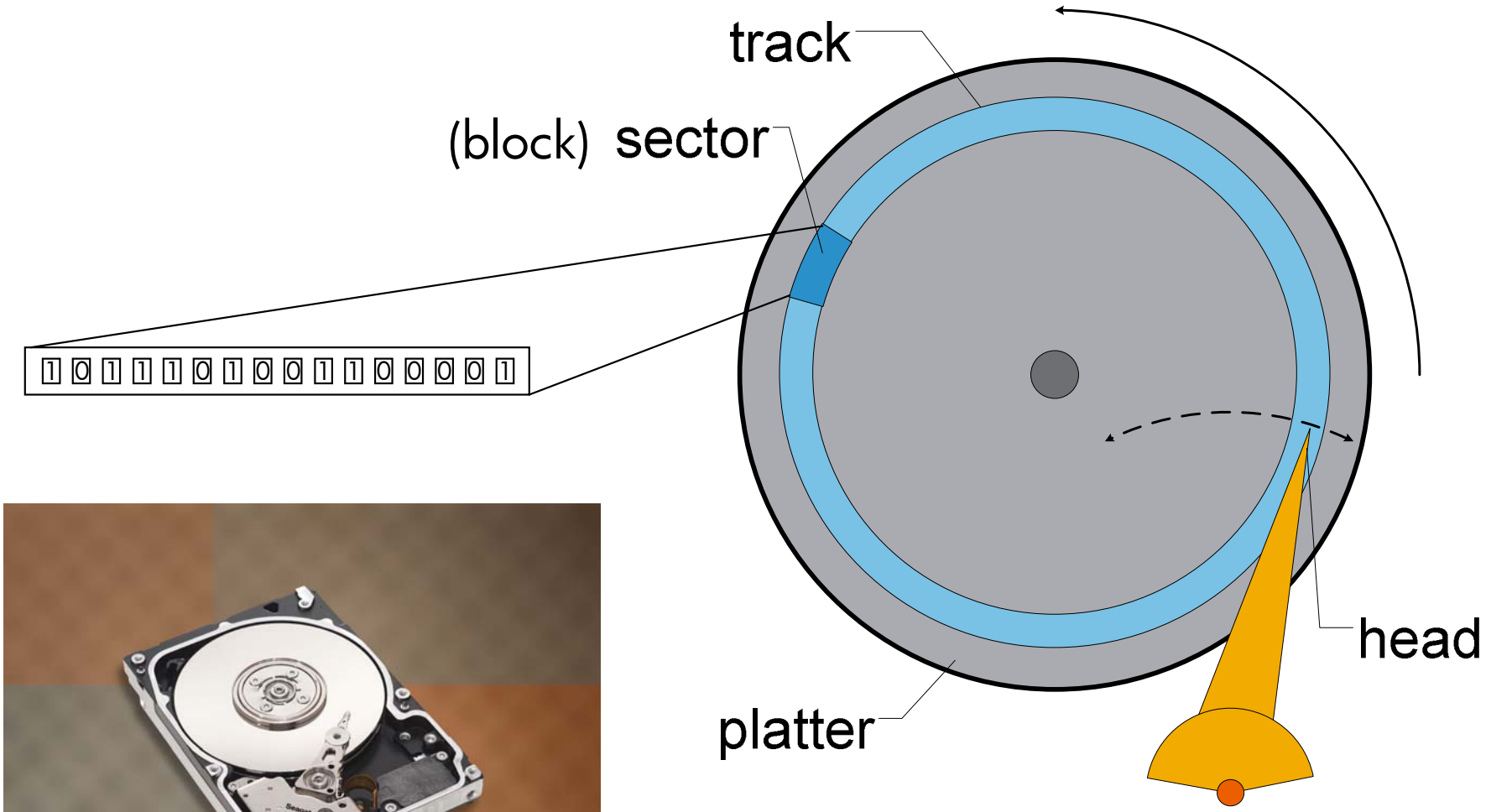


Storage infrastructure: it's all about blocks

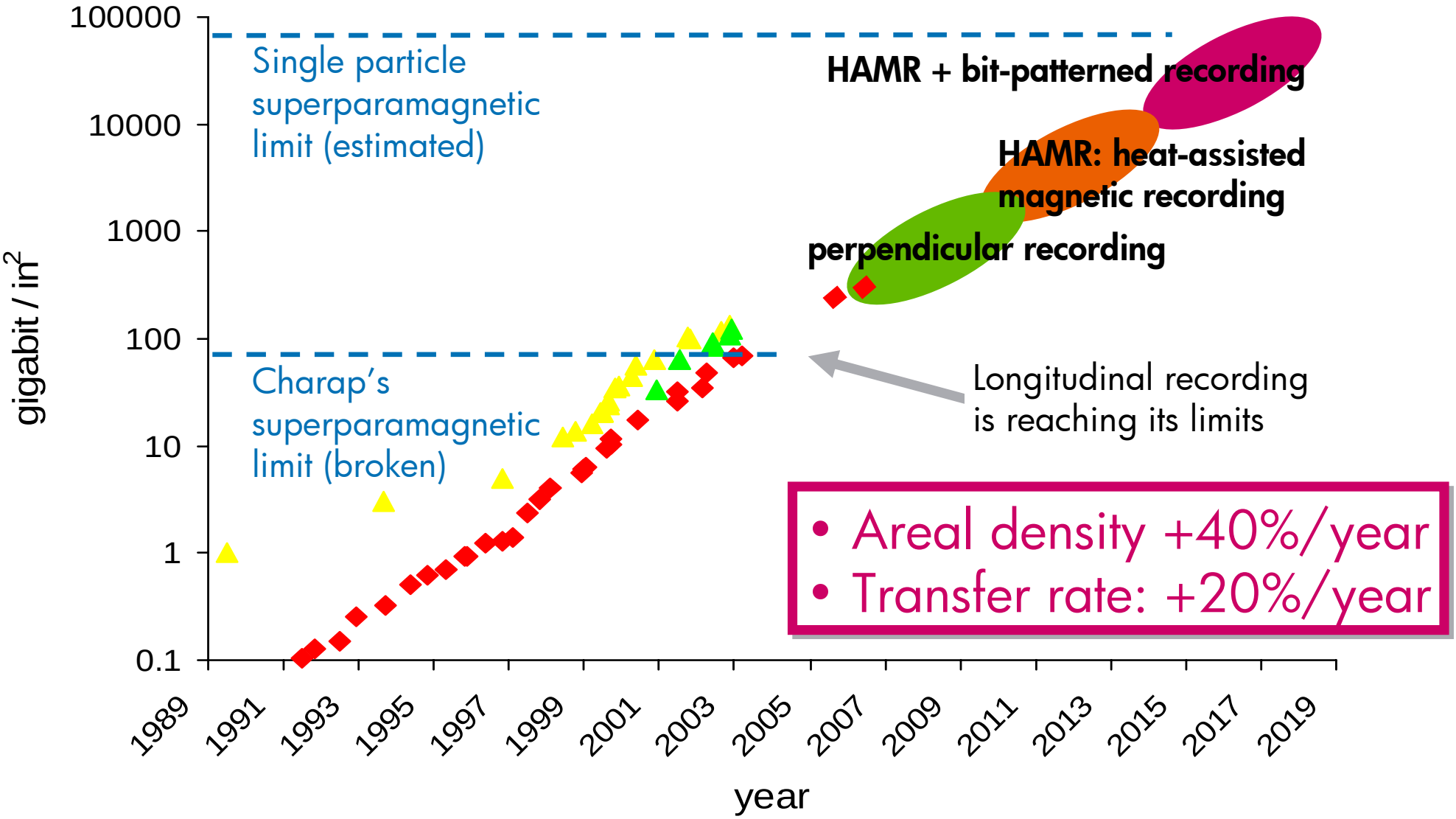
- contiguous set of bytes (characters)
- fixed length (typically 512 bytes)
- stored on disks or arrays of disks (and tapes)



Disk drives simplified (2)



Disk drive trends: areal density



source: Seagate

Disk drive trends: scaling up a disk access

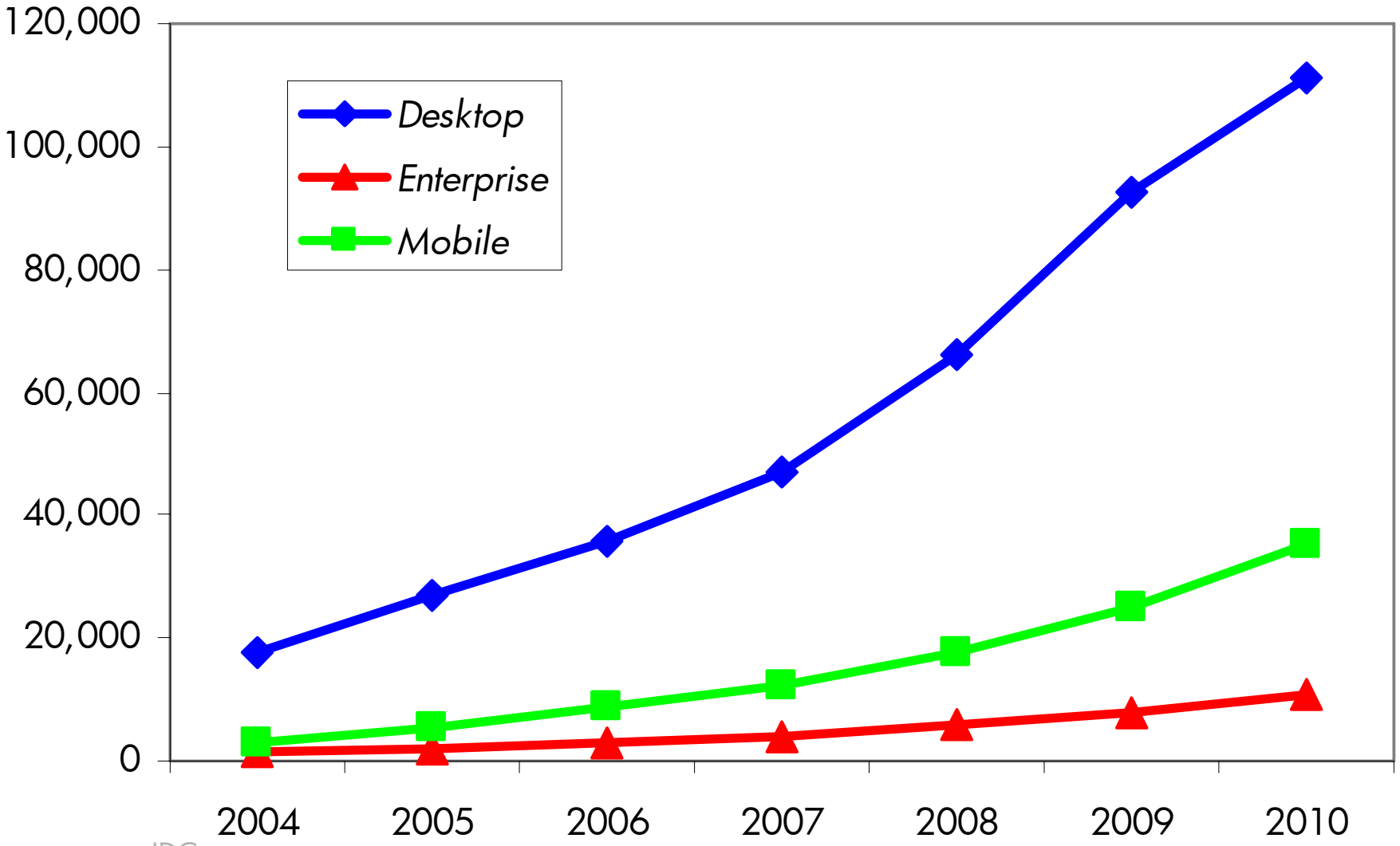
	real time	*scaled-up time*
cache	1ns	look-up on paper: few seconds
memory	100ns	retrieve book from room: 1 minute
disk	5ms	get entire bookcase delivered: **35 days** new bookcases: 300/day

Types of drives

- Segments
  - Consumer Electronics
  - Mobile
  - Desktop
  - Enterprise
- Differentiators
  - capacity
  - performance
  - reliability
  - form factor (size)
  - interface
  - price ($/GB)
  - supplier support

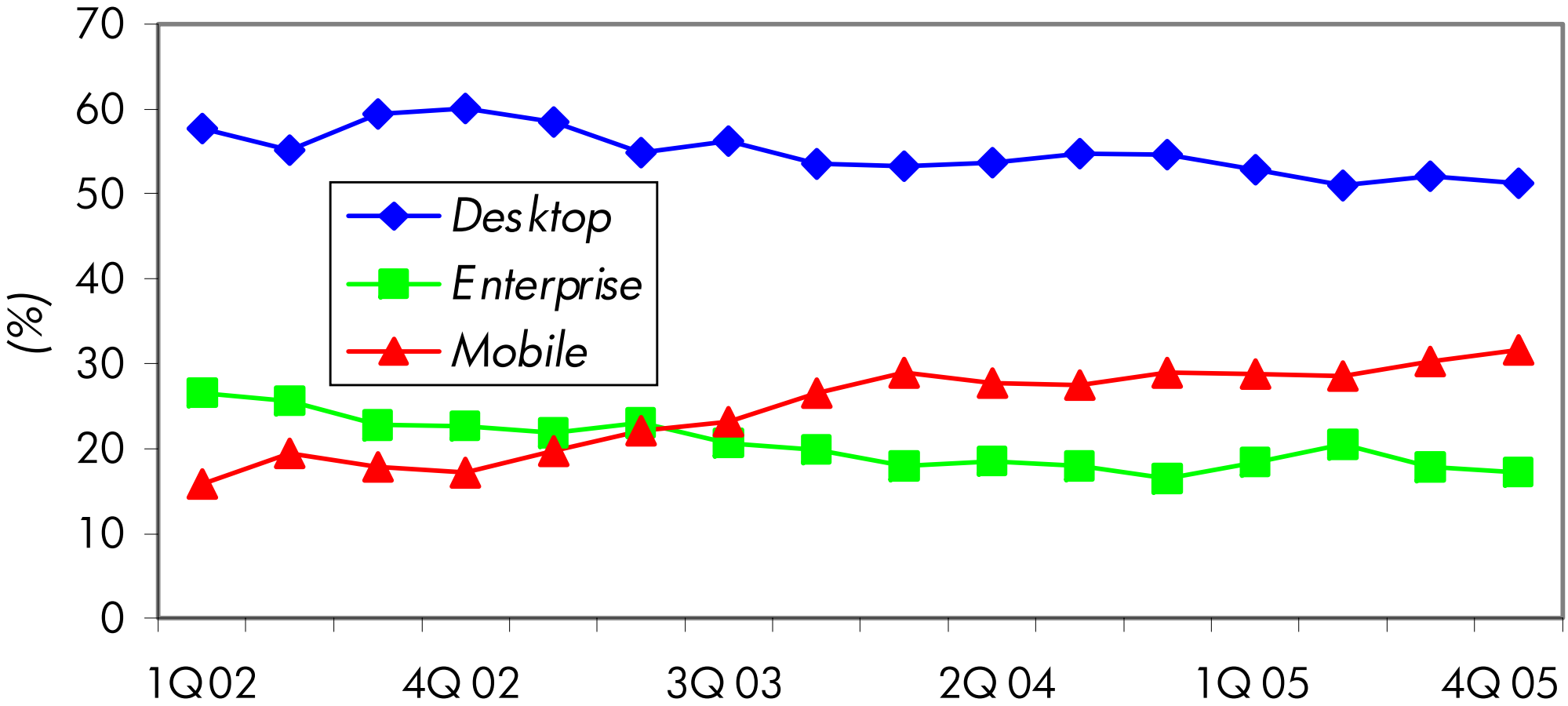
Disk drive shipments (capacity) by drive type

Petabytes shipped worldwide



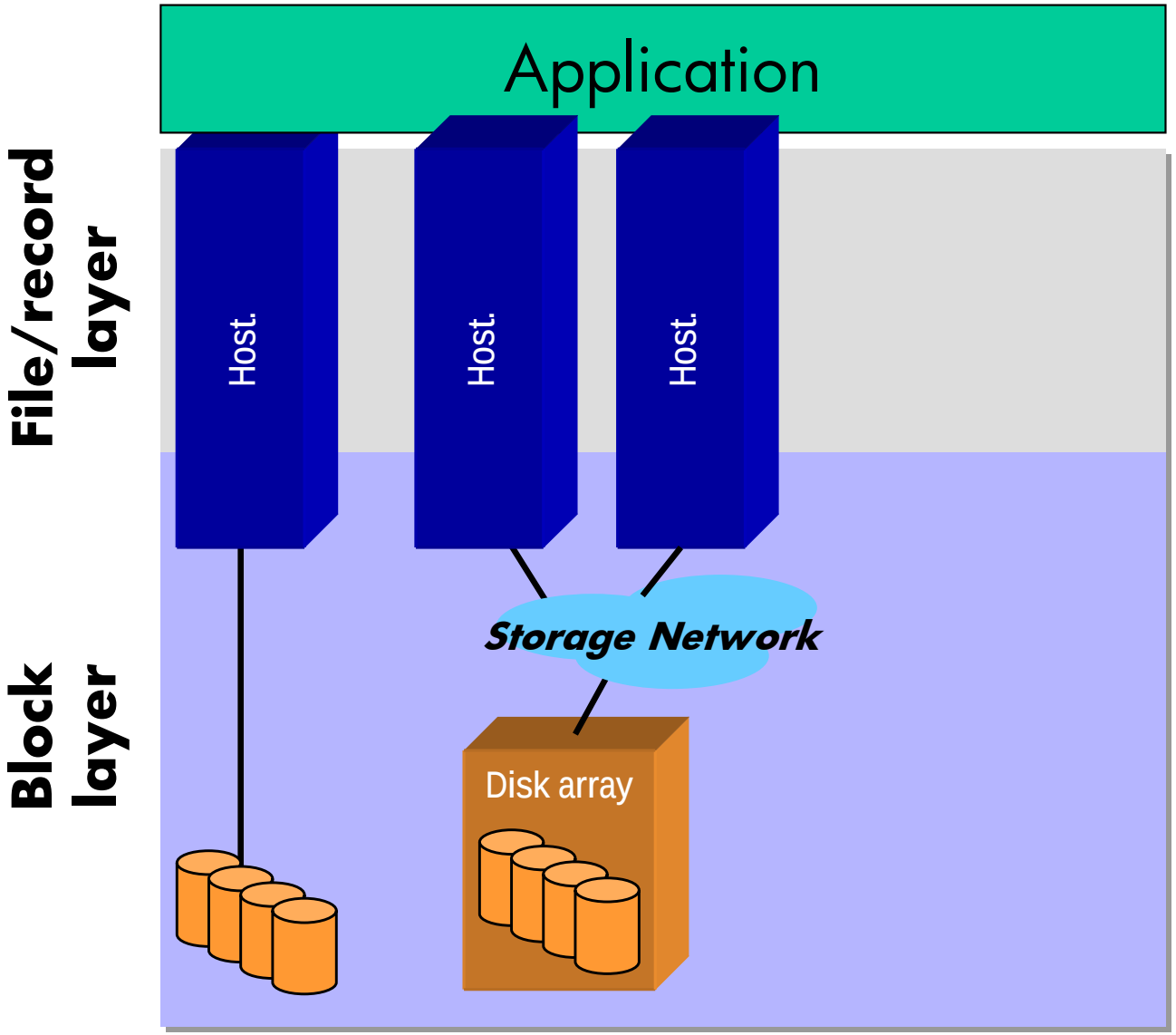
source: IDC

Disk drive shipments (revenue) by drive type



source: IDC

Block device attachment types



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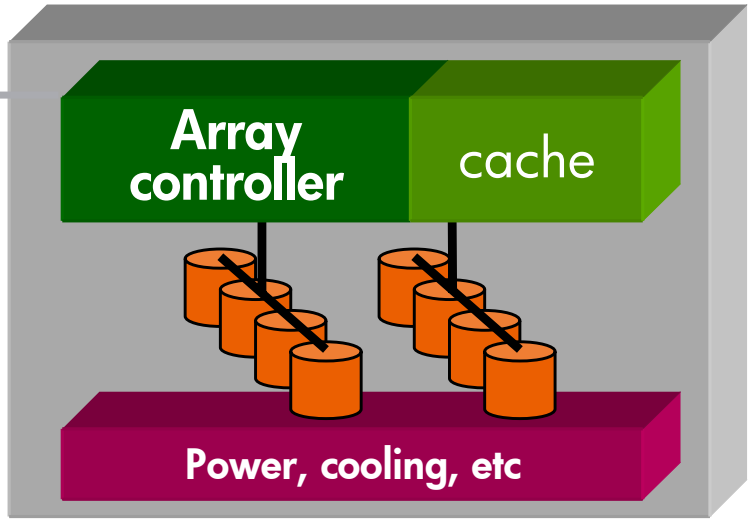
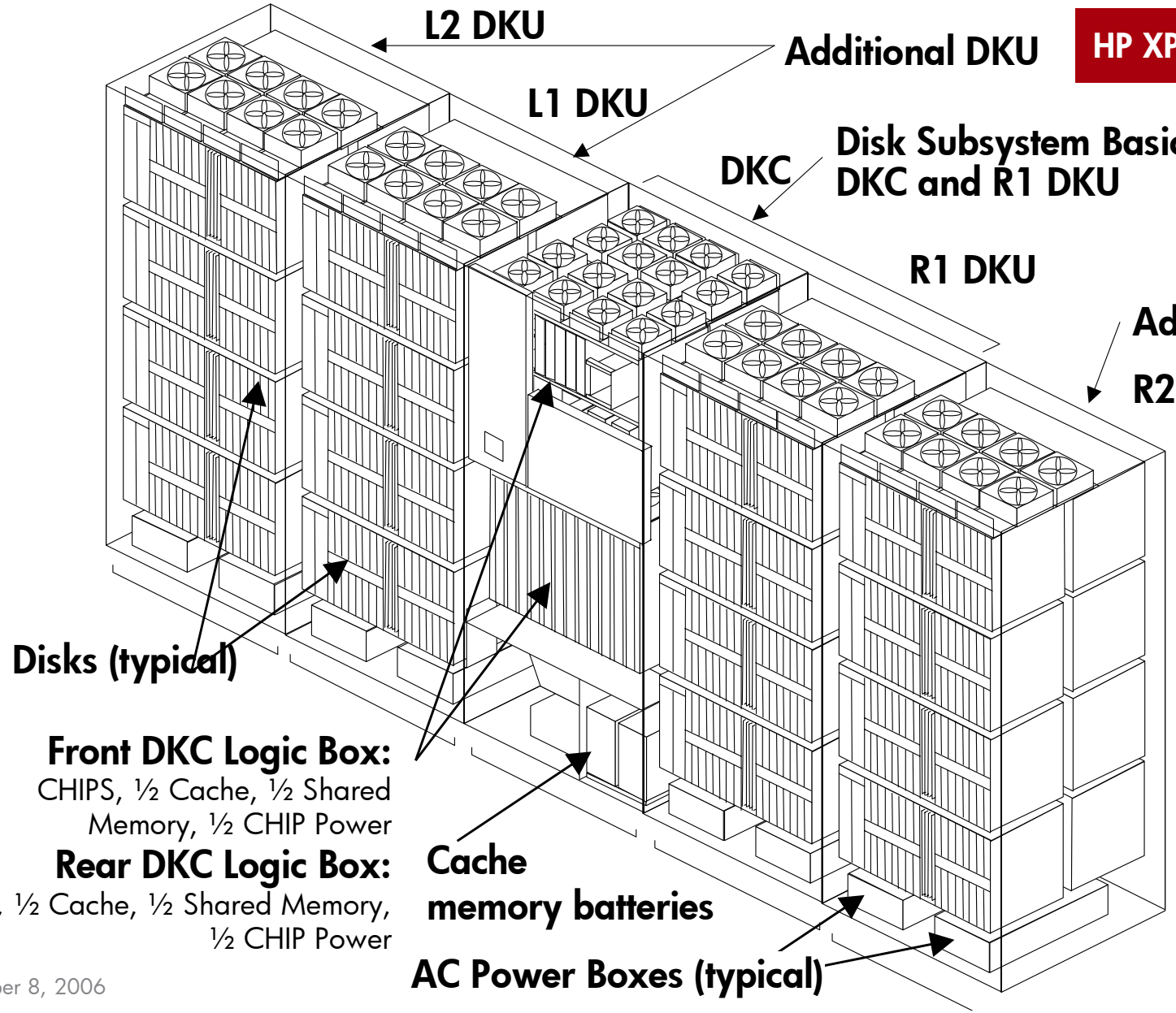
Disk arrays

- A disk array is just:
  - mechanical enclosure
  - power and cooling
  - controller(s)
  - network connection
- That offers:
  - failure protection
  - aggregation (capacity, performance)
  - virtualization

HP MSA disk array

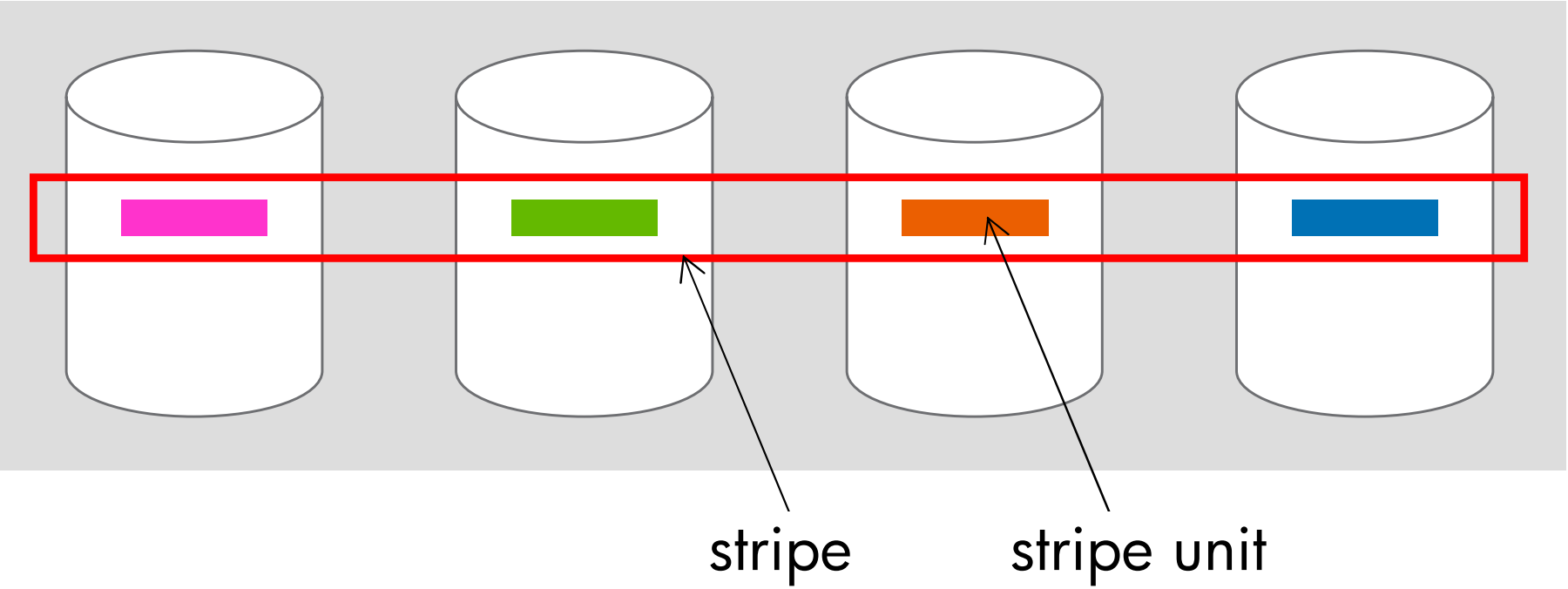


Disk arrays

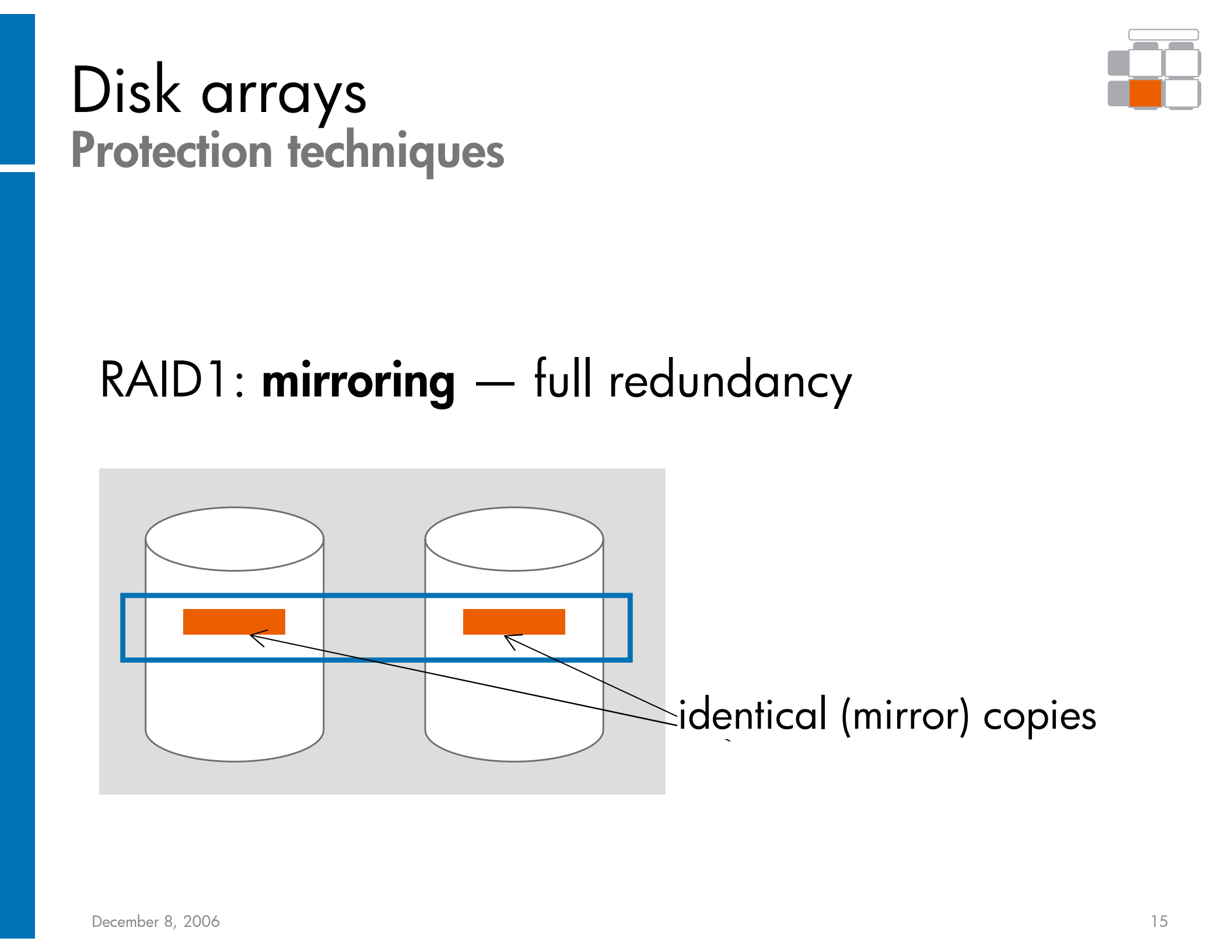

L2 DKU
Additional DKU
HP XP1024 disk array
L1 DKU
DKC
Disk Subsystem Basic Unit
DKC and R1 DKU
R1 DKU
Additional DKU
R2 DKU
Disks (typical)
Front DKC Logic Box:
CHIPS, ½ Cache, ½ Shared Memory, ½ CHIP Power
Rear DKC Logic Box:
ACPs, ½ Cache, ½ Shared Memory, ½ CHIP Power
Cache memory batteries
AC Power Boxes (typical)

Disk arrays
Protection techniques

RAID0: **striping** — no redundancy



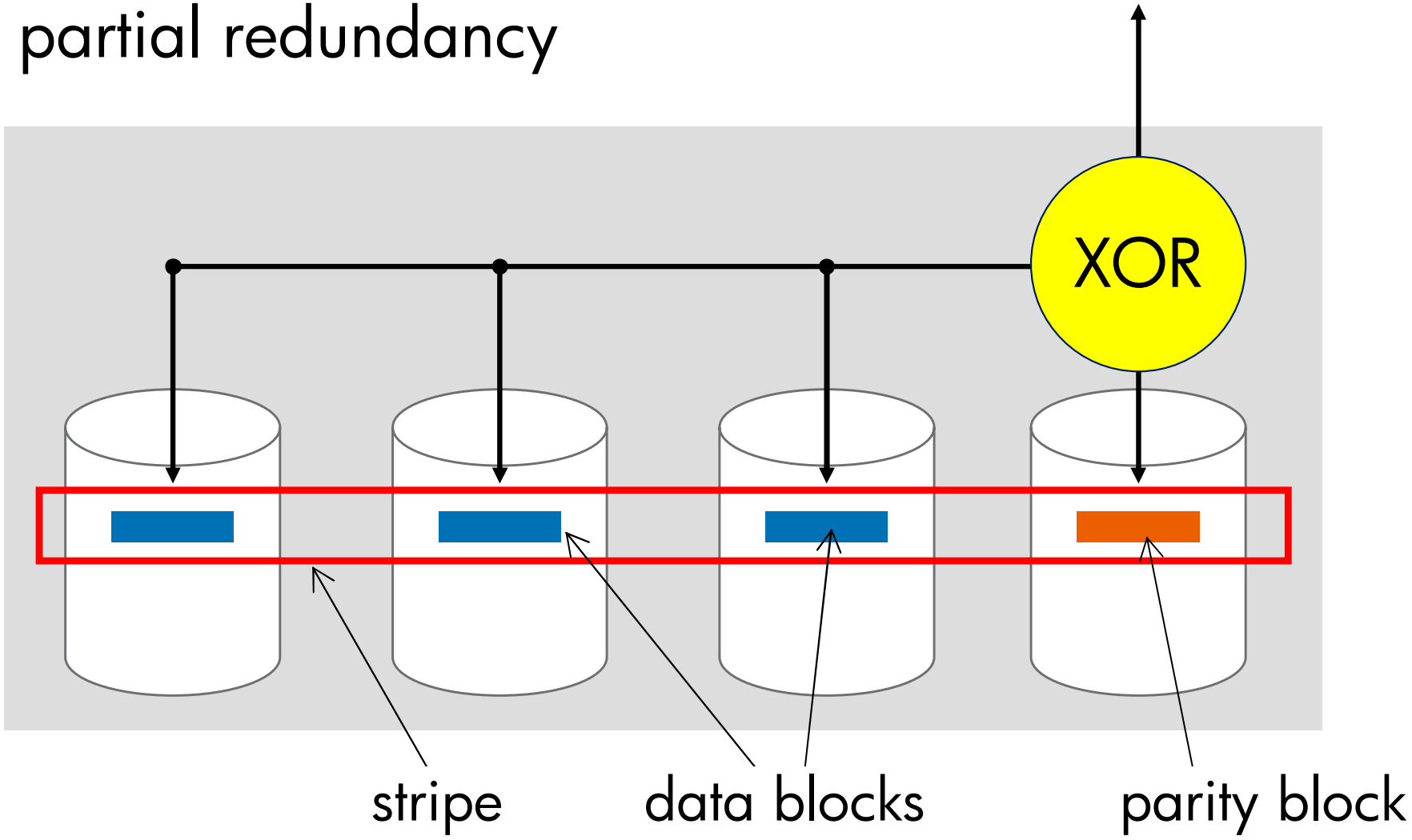
Disk arrays
Protection techniques



RAID1: **mirroring** — full redundancy

Disk arrays
Protection techniques

RAID5: **parity-protection** — partial redundancy



Disk arrays
aggregation + virtualization

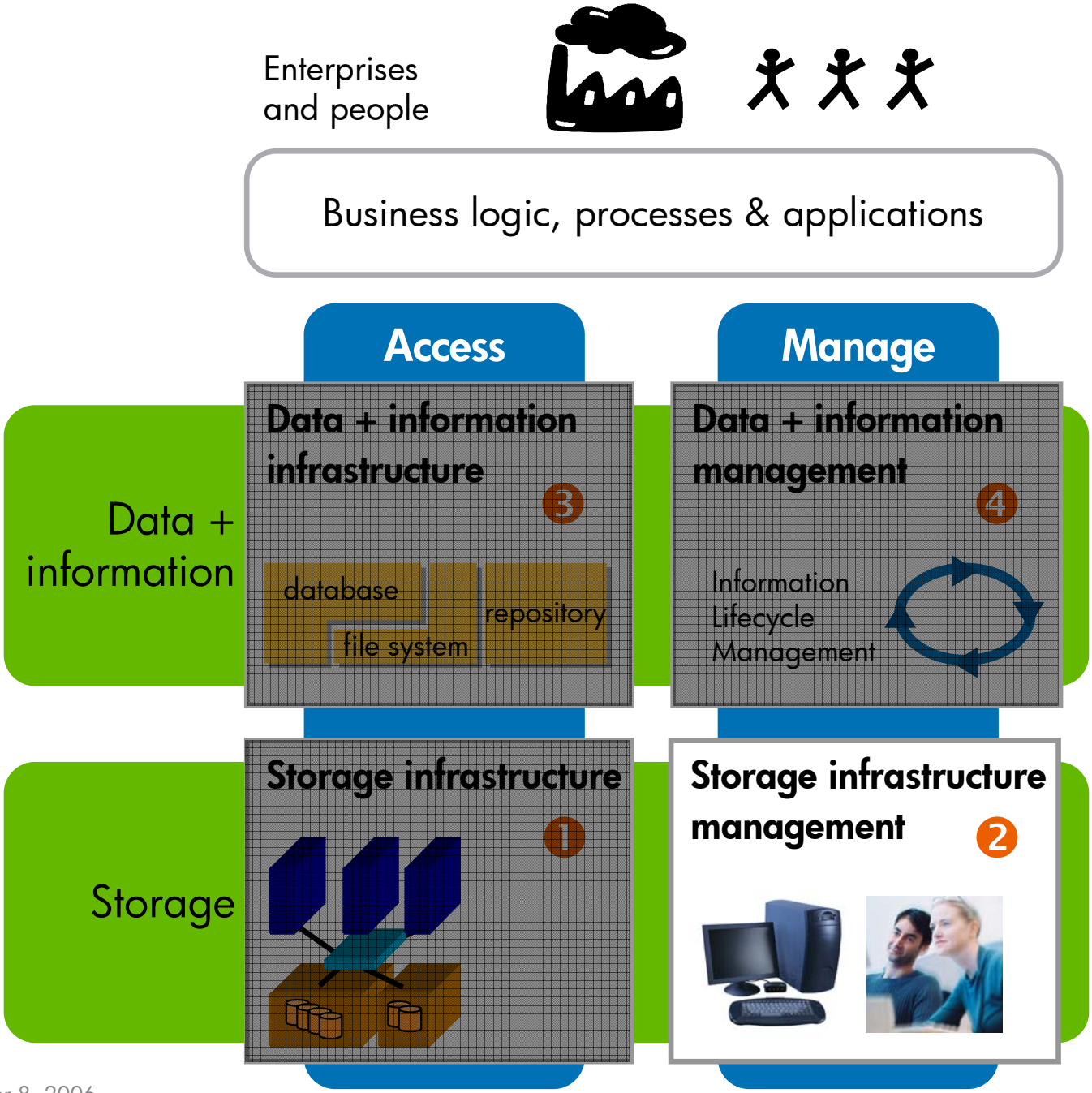
- "Slice and dice" block storage into *volumes*
  - larger or smaller than a single disk
- Usually done by software on the disk array
  - but it can also happen in other places

Don’t forget tapes …

Storage infrastructure
key messages

- It's all about *blocks*
- The physical characteristics of *disk drives* dictates a lot of the technology for block storage
  - performance
  - failure tolerance
- *Software* adds value to and differentiates disk arrays via aggregation and virtualization

Storage infrastructure management

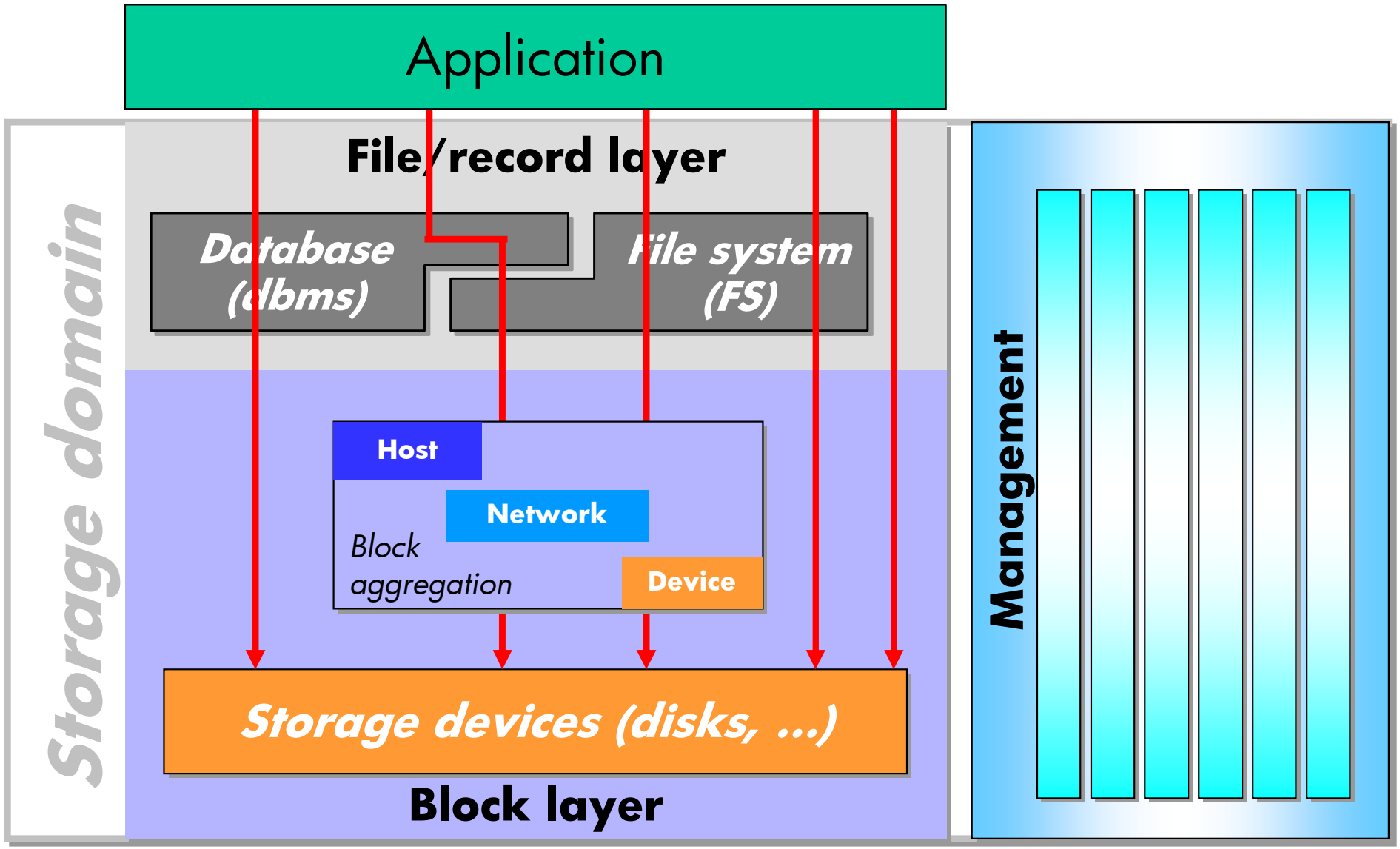


Q: what **is** storage management?
A: all of these …

1 Activate licensed features in fabric elements
2 Add SAN resource domain (fabric + devices) to existing installation
3 Add host to existing FC fabric
4 Add hub to existing FC loop/fabric
5 Add peripheral disk device to bridge
6 Add peripheral disk device to storage array
7 Add port to storage array
8 Add switch to existing FC fabric
9 Add tape drive or library to bridge
10 Analyze SAN topology for single points of failure
11 Analyze SAN topology for traffic hot spots
12 Analyze device behavior to predict failures
13 Assign IP addresses to SAN components
14 Assign OS to run in partition/on platform
15 Assign action for event response
16 Assign free volume to OS/application
17 Audit actual configuration against planned/intended config
18 Audit firmware configuration
19 Audit software configuration
20 Boot OS in partition/on platform
21 Change OS or OS FC driver revision
22 Change cabling to service/management modem(s)
23 Change cabling to service/management network hub
24 Change cabling to service/management serial hub
25 Change cabling to service/management server(s)
26 Change fabric cabling to HBA
27 Change fabric cabling to use spare port
28 Change fabric internal topology (ISL's)
29 Configure and compile OS kernel
30 Convert existing fabric to cascaded fabric
31 Convert existing fabric to fully redundant fabric
32 Convert host bus adapter from FC-SW to FC-AL or vice versa
33 Convert single-initiator SCSI bus to multi-initiator
34 Convert two existing fabrics into a single fabric
35 Diagnose I/O errors
36 Diagnose directed path/device I/O (online, offline)
37 Diagnose system crash/hang
38 Download FC host bus adaptor firmware
39 Download FC switch firmware
40 Download storage array firmware
41 Download tape library firmware
42 Failover broken host bus adapter
43 Failover broken intra-switch port or trunk (ISL)
44 Failover broken storage array port or link
45 Failover broken switch port or link
46 Find physical location of specific device or fabric element
47 Install new FC-AL loop
48 Install new FC-SW fabric
49 Install new host
50 Install service/management software (servers, agents)
51 Install software, patches, service packs
52 Install storage array (Shark, EMC, HDS, Clariion)
53 Install tape system with shared drives
54 Install tape system with unshared drives and shared robotics
55 Mount OS file systems
56 Online/offline FC-SCSI bridge
57 Online/offline OS volume manager objects (mirrored, concatenated, etc)
58 Online/offline host bus adapter
59 Online/offline intra-switch trunk (ISL)
60 Online/offline path in multipath-capable OS
61 Online/offline peripheral device
62 Rebuild system for disaster recovery
63 Replace FC-AL hub
64 Replace FC-SCSI bridge (SAN Data Gateway, NUMA-Q FC Bridge)
65 Replace FC-SW switch (single switch fabric, multiple switch fabric)
66 Replace SAN management server
67 Replace failed director/controller in storage array
68 Replace host bus adaptor
69 Replace host
70 Replace peripheral device
71 Replace platform management server
72 Replace tape library robotics
73 Reserve tape media and storage slots within tape library
74 Reset/power-cycle FC-SCSI bridge
75 Reset/power-cycle entire installation (power-fail, first bringup)
76 Reset/power-cycle host platform
77 Reset/power-cycle peripheral devices (on bridge)
78 Reset/power-cycle storage array
79 Run offline diagnostics (using idle/disused system components)
80 Run online diagnostics (using "active" system components)
81 Sanitize used fabric elements to safely reuse in new fabric (clear NVRAM)
82 Set/view "POST" diagnostic level
83 Set/view "business continuation volumes" (BCV)
84 Set/view OS configuration files/registry
85 Set/view OS volume manager volumes
86 Set/view SNMP trap destination
87 Set/view backup schedule
88 Set/view event reporting threshold
89 Set/view event-/error-report destination
90 Set/view online diagnostics error threshold trigger
91 Set/view phone-home/email-home destination
92 Set/view service/management authentication (passwords)
93 Set/view storage array LUN masking and LUN mapping
94 Set/view storage array volume definition
95 Set/view switch ISL topology
96 Set/view switch zoning
97 Set/view system boot parameters (device, flags, etc)
98 Set/view vital product data (diary RAM)
99 Test (acceptance) post-install/-repair
100 View/search system logs (OS, platform, fabric element, etc …

list from
Stuart Friedberg,
Veritas

SNIA Shared Storage Model



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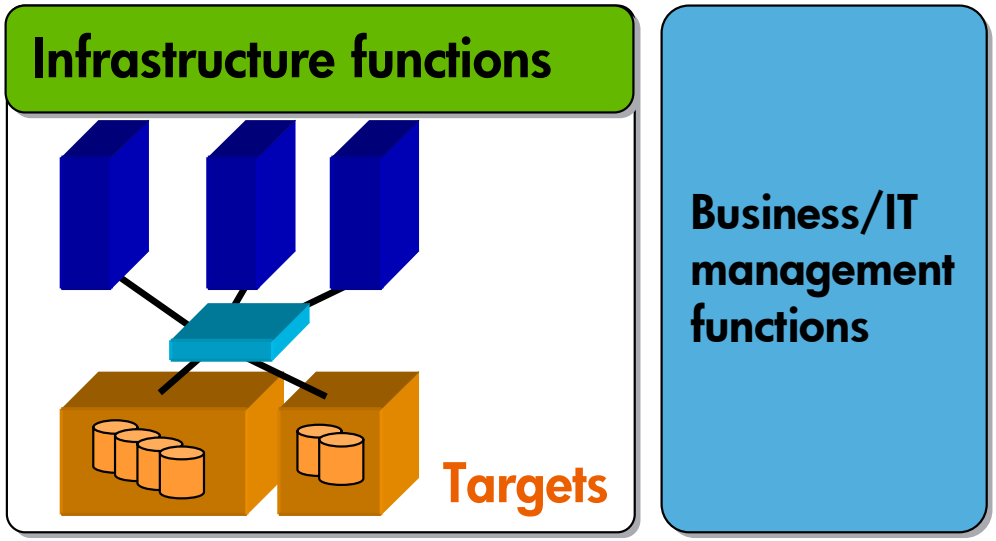
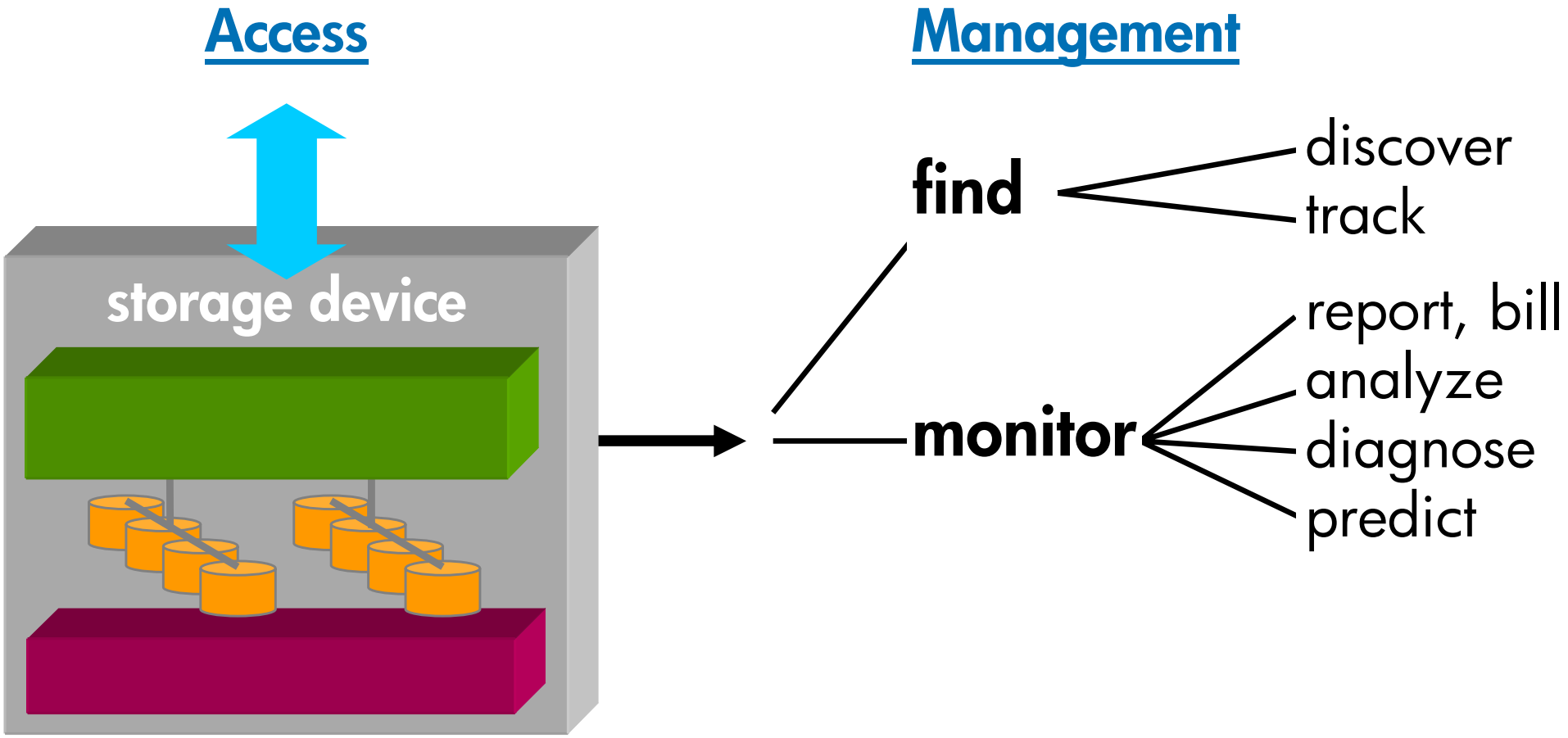
Q: what **is** storage management?
A: divide the space

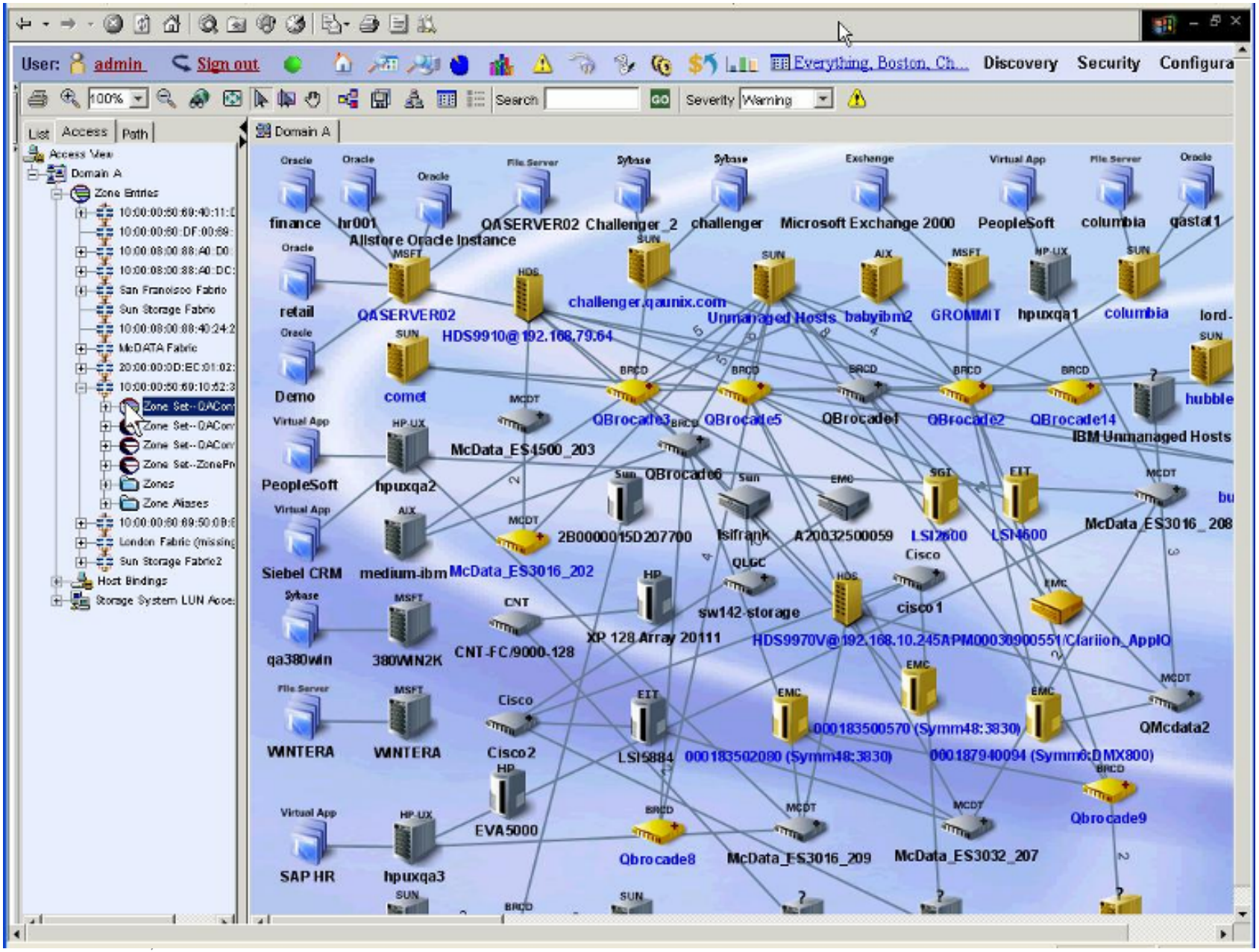


- **targets**
  - managing *things*
- **infrastructure functions**
  - managing *capabilities*
- **business/IT management functions**
  - achieving *goals*

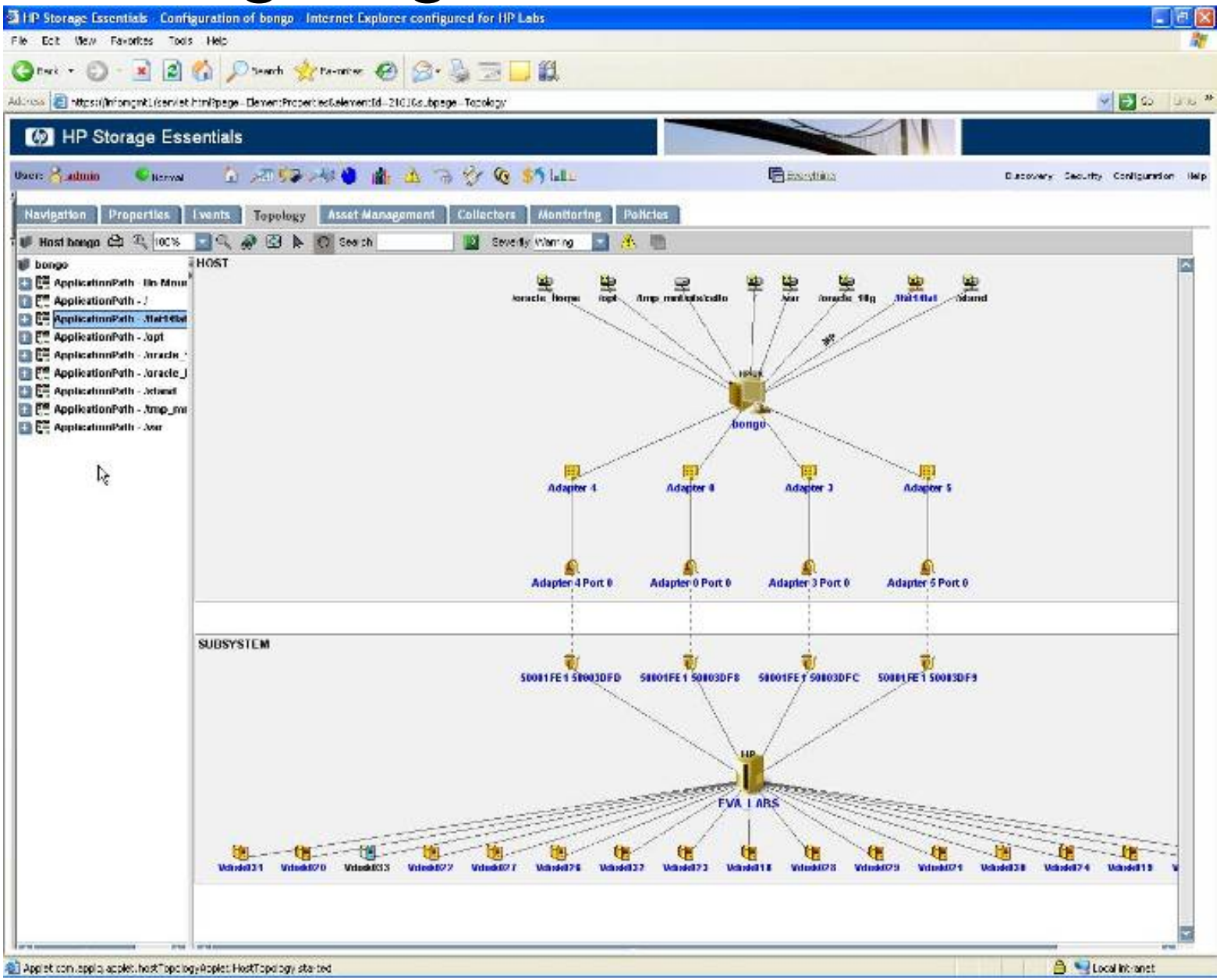
Target management
Access and management

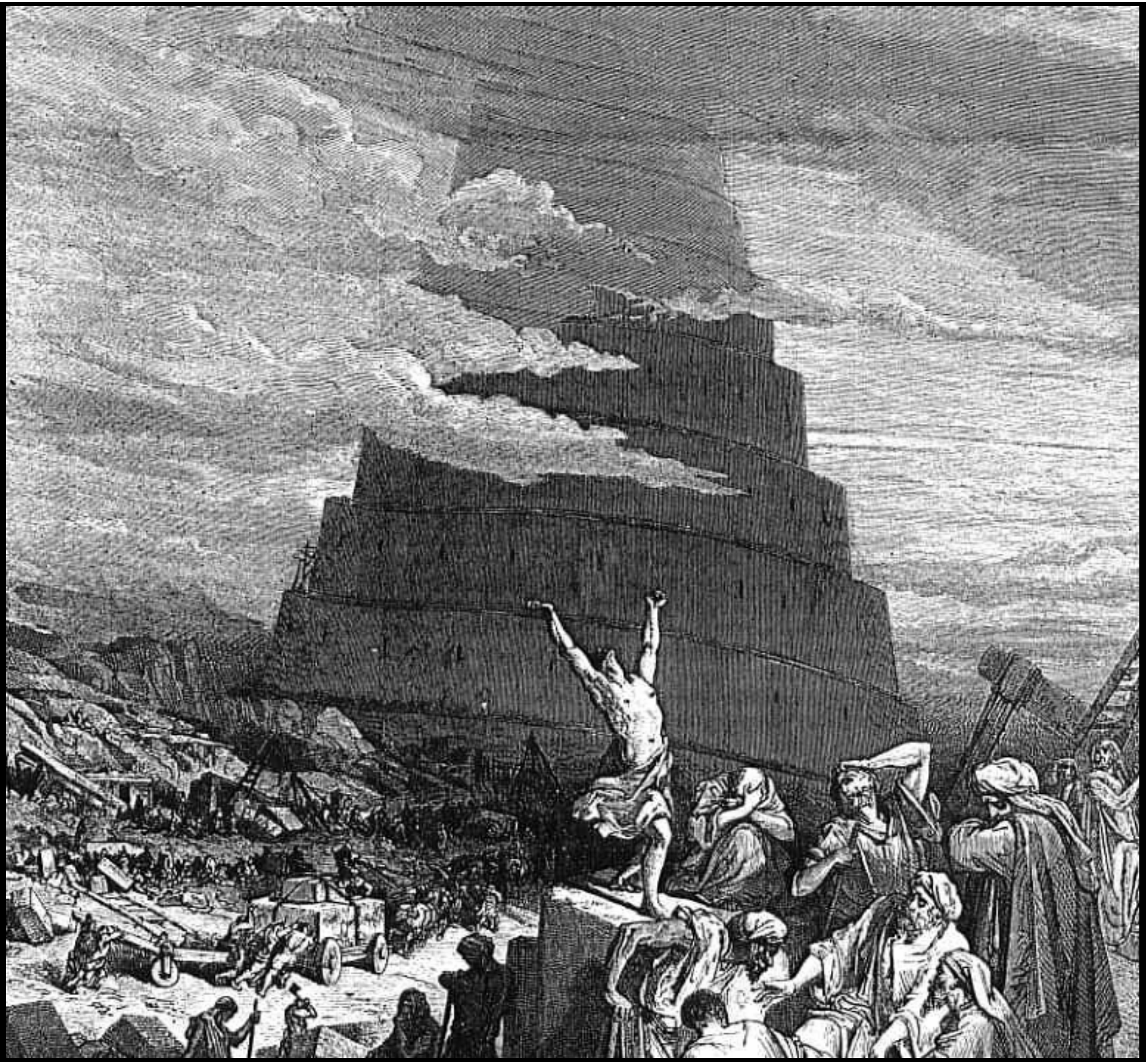


Target management
Finding targets

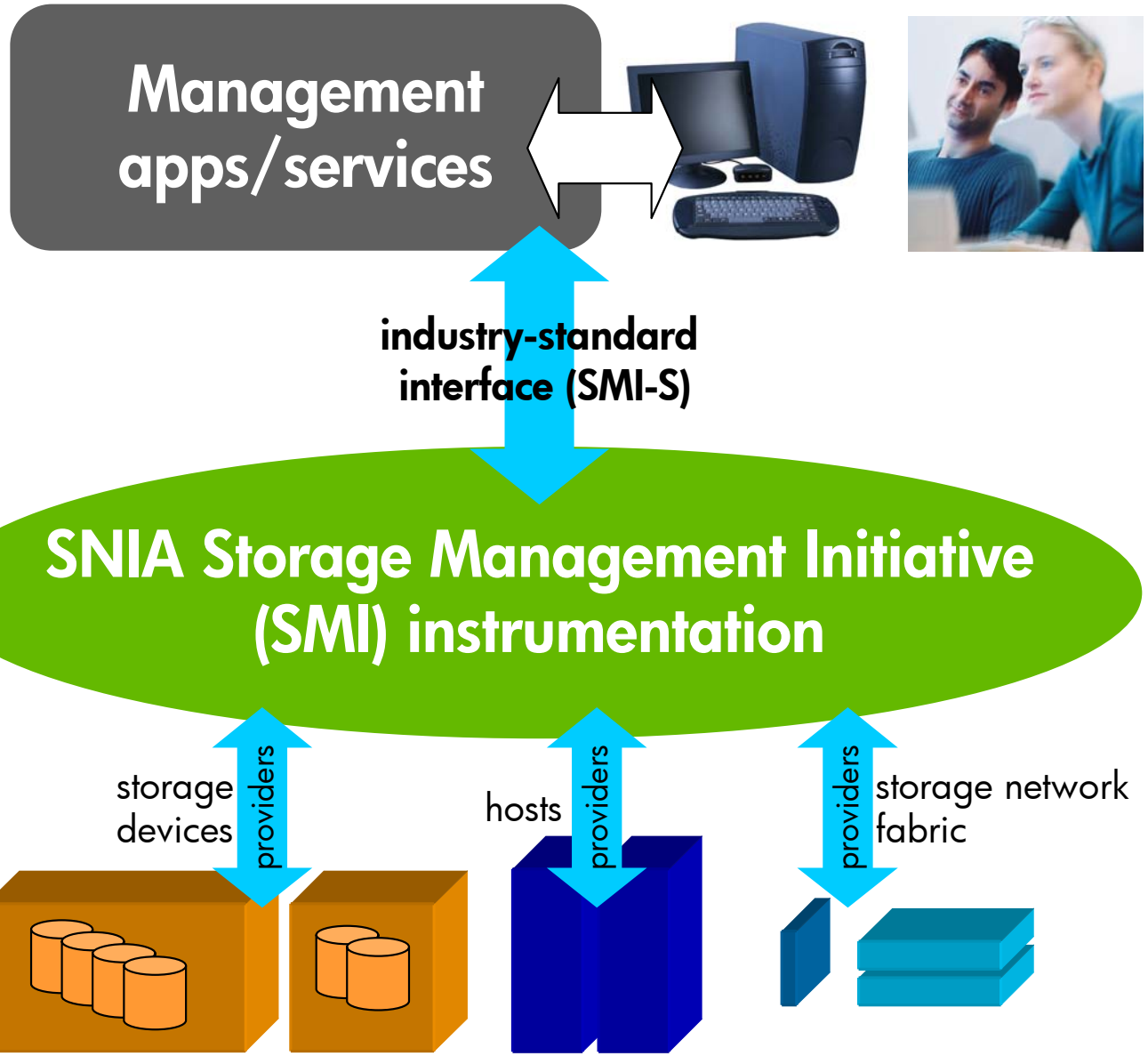


Target management
Finding targets

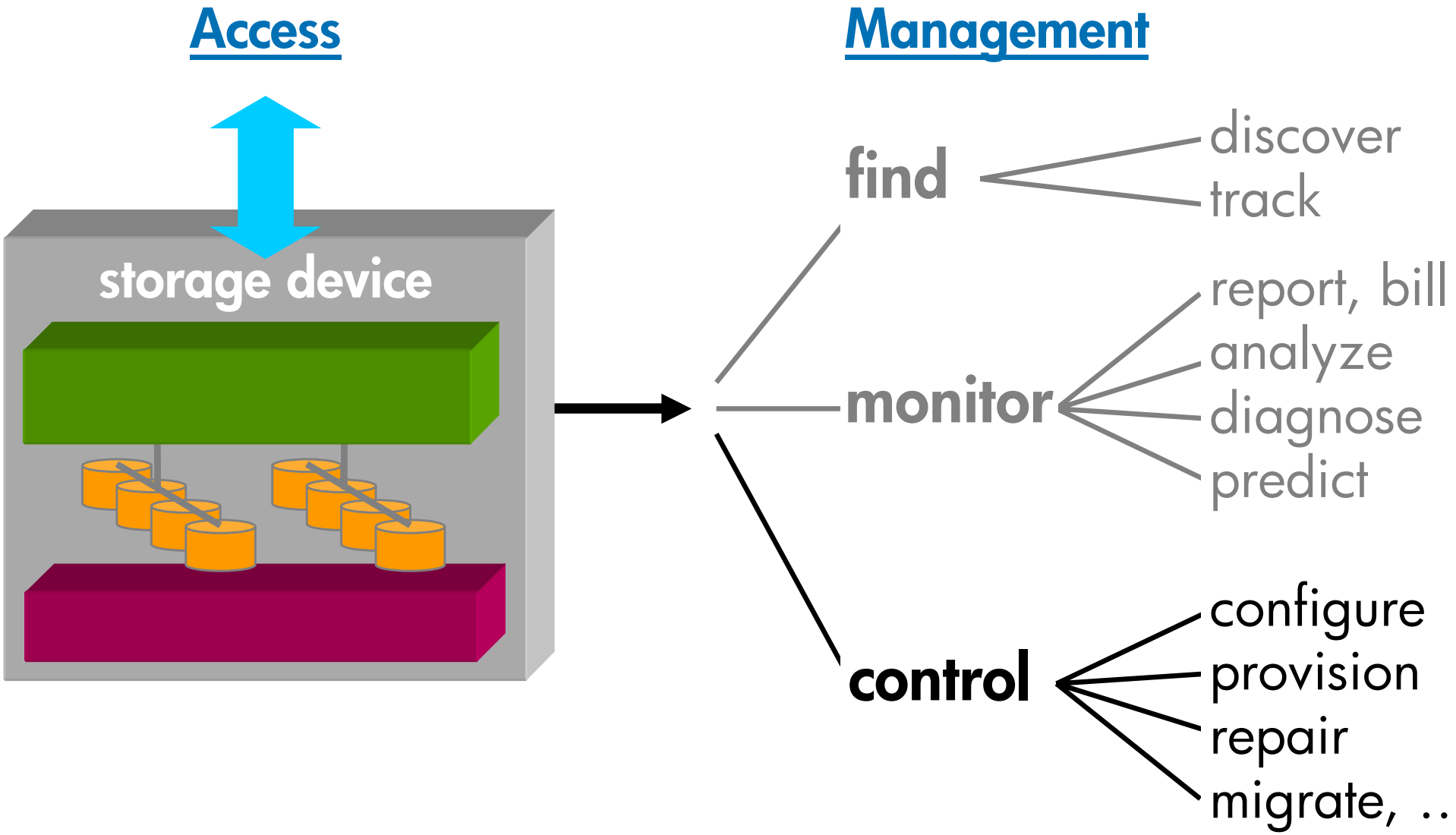




Target management
SMI: a standard monitoring platform



Target management
Access and management



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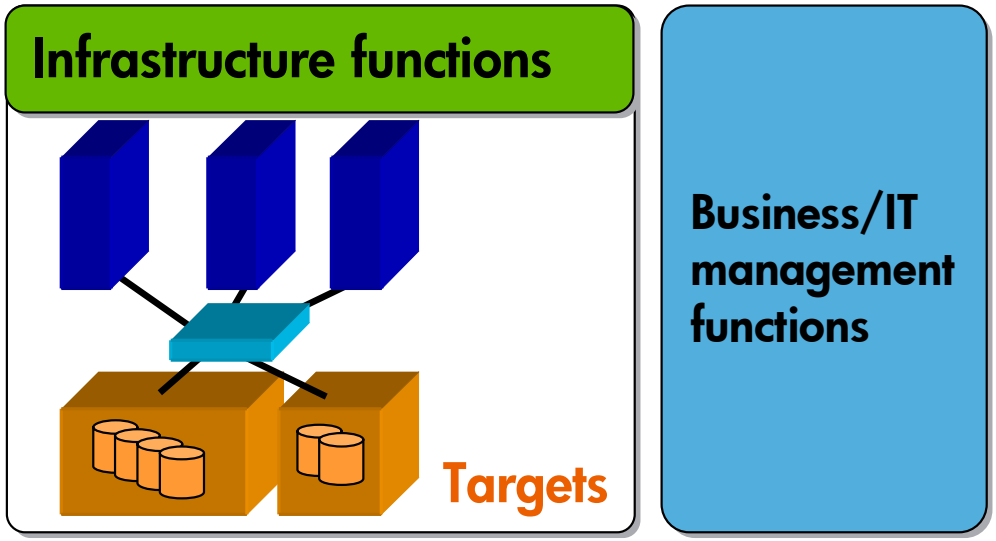
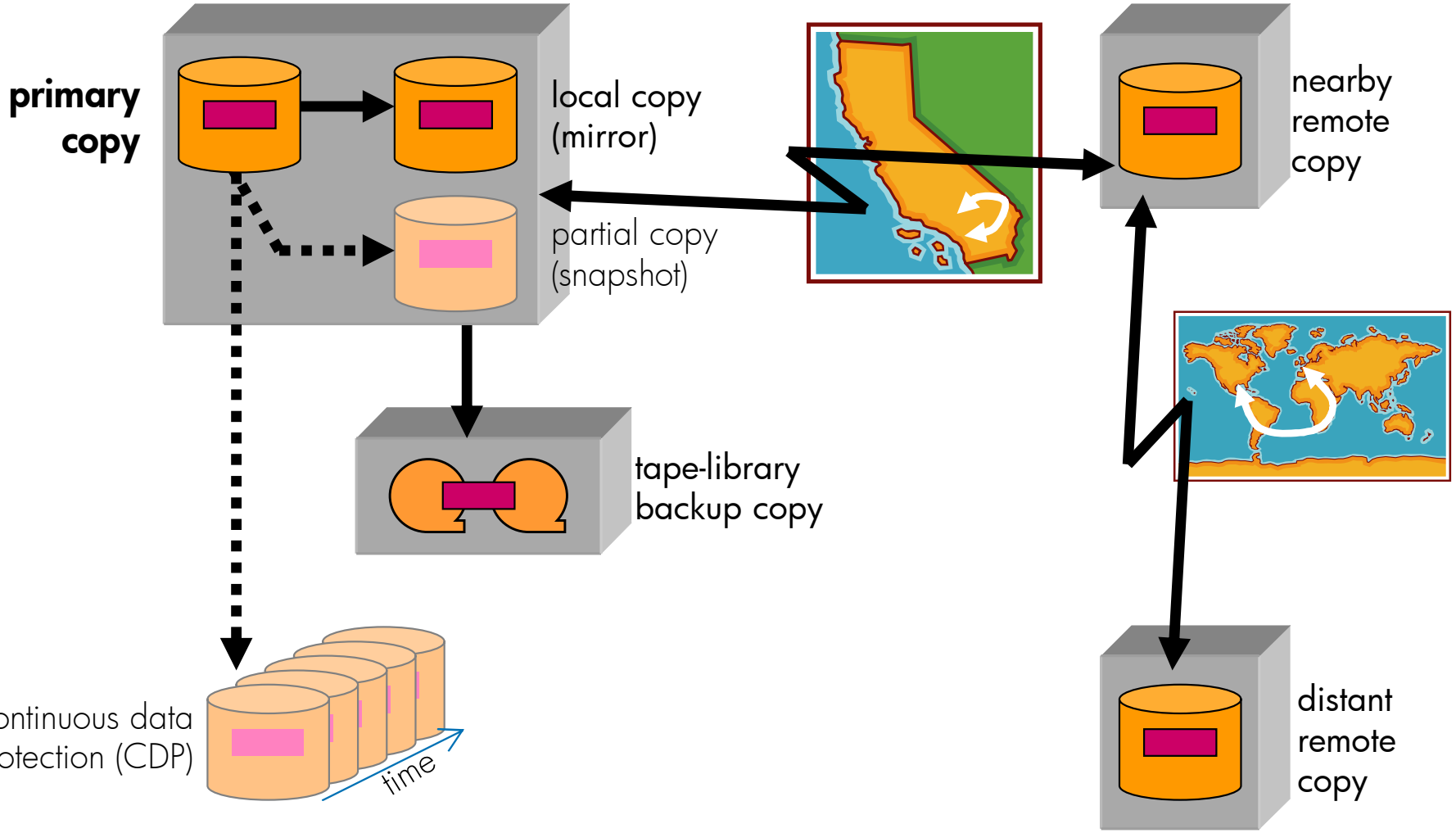


- **targets**
  - managing *things*
- **infrastructure functions**
  - managing *capabilities*
- **business/IT management functions**
  - achieving *goals*

Infrastructure functions
Data replication



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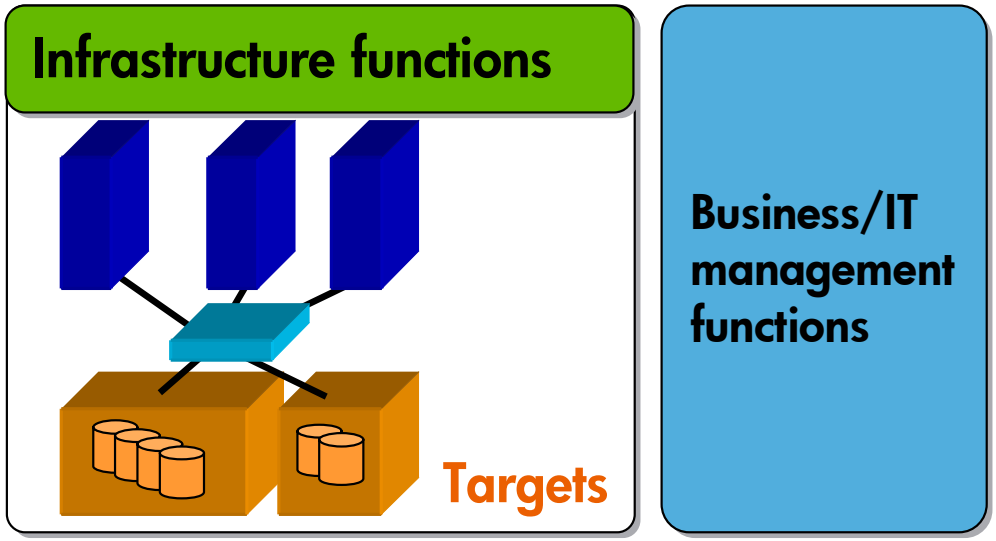
A: divide the space



- **targets**
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  - achieving *goals*

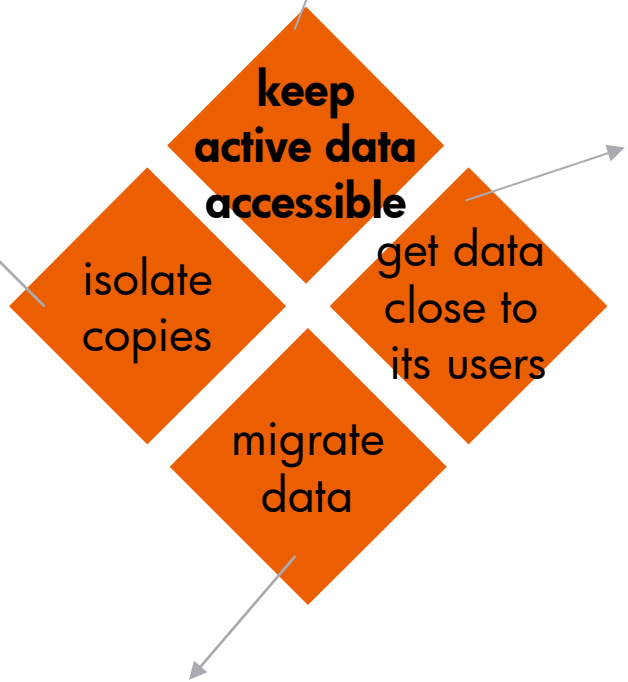
Business/IT management functions
Why replicate data?

Keep active data accessible

- **Business continuity** (business always up)
- **Failure/disaster tolerance** (hide faults)
- **Failure/disaster recovery** (pick up after faults)

Isolate separate copies

- for performance
- for protection



Get data close to its users

- e.g., caching

Migrate data

- while it is being accessed

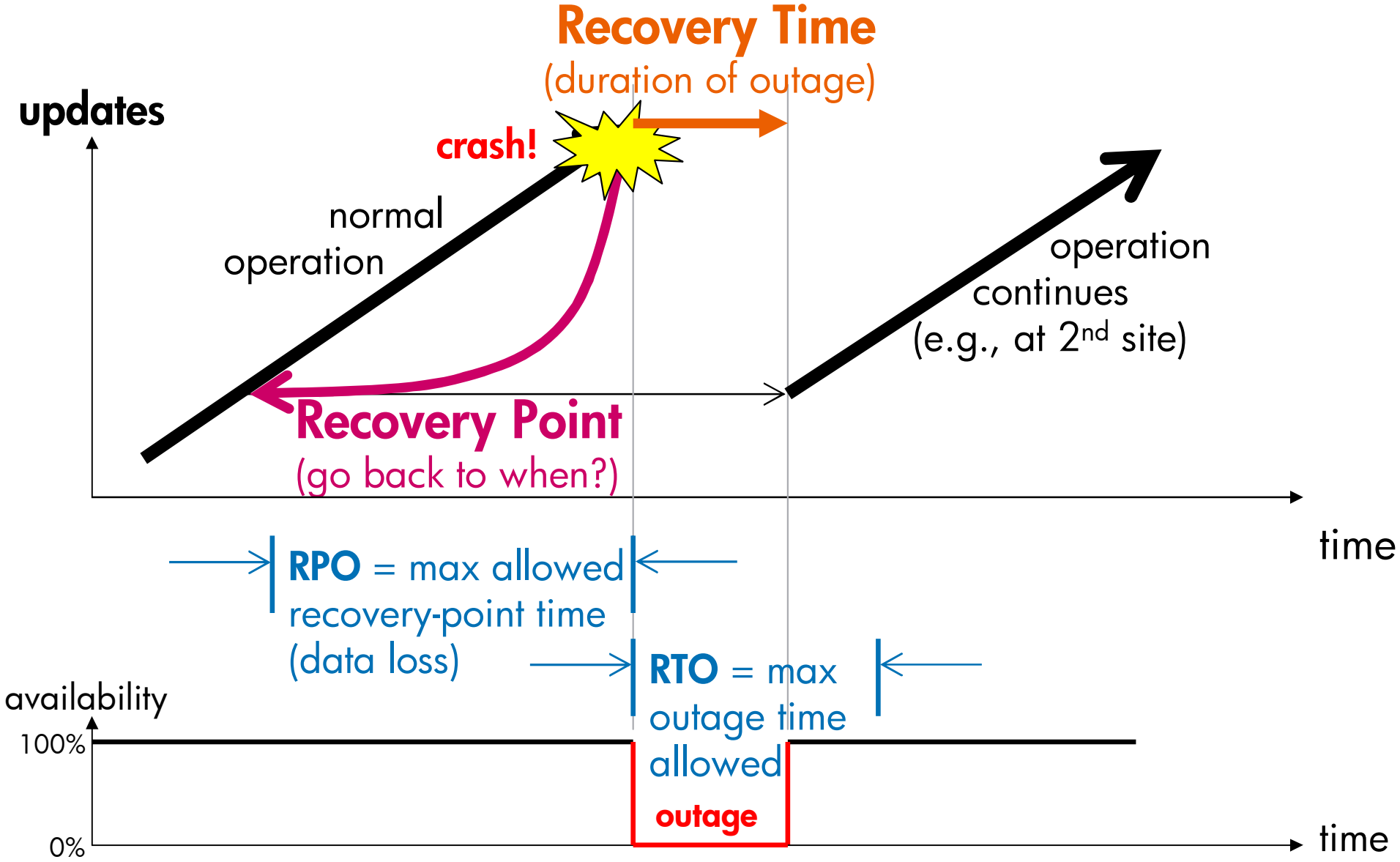
Business/IT management functions
Quality of Service (QoS) objectives

- **QoS goals** = "I want …"
  - security, performance
  - reliability, availability
  - consistency, correctness

- **QoS measurement** = "what is happening?"
  - monitor, report, analyze, diagnose, predict

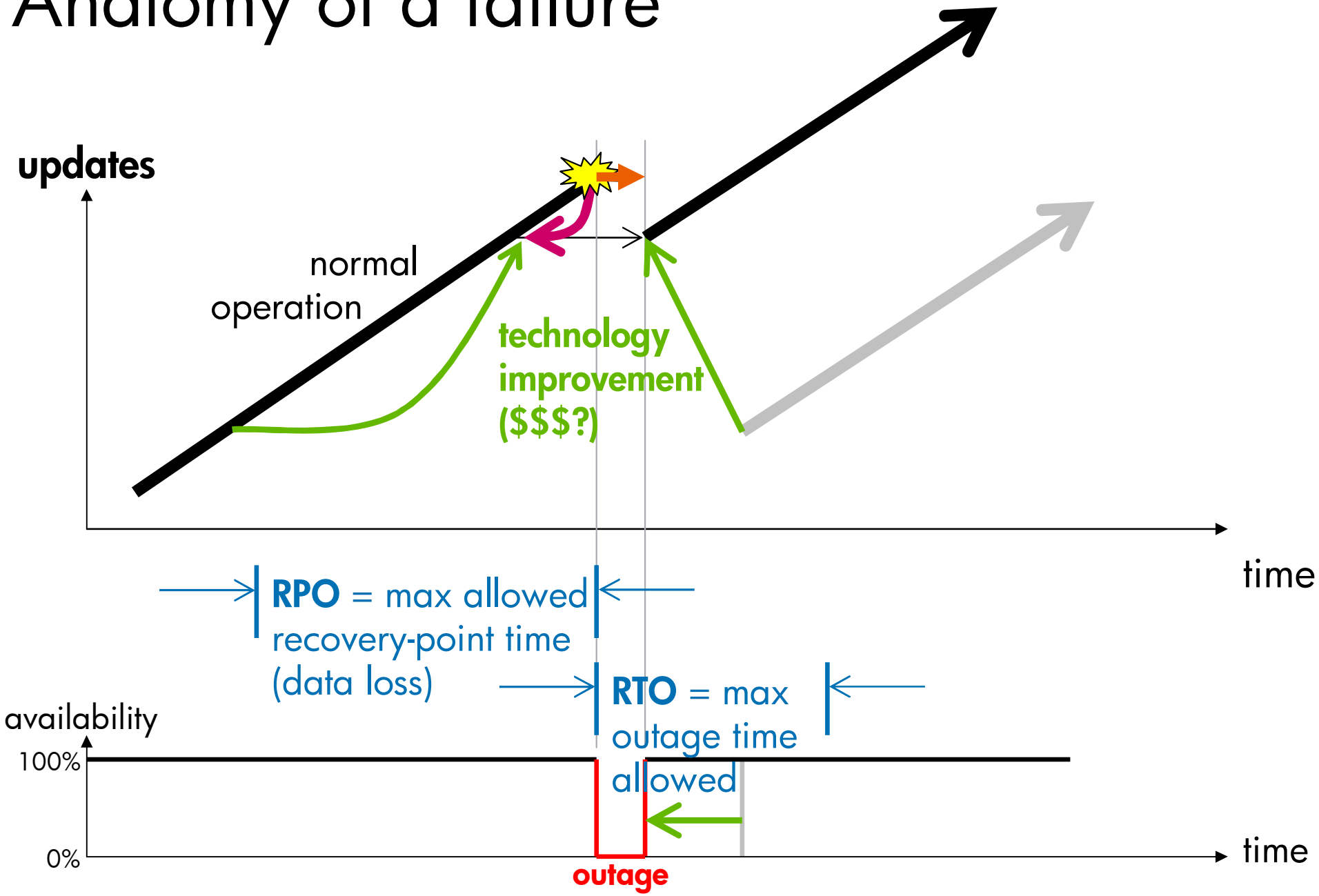
- **QoS enforcement** = "make sure that …"
  - bad stuff doesn't happen (stop it)
  - good stuff does (adapt)

Management function: protect data
Anatomy of a failure

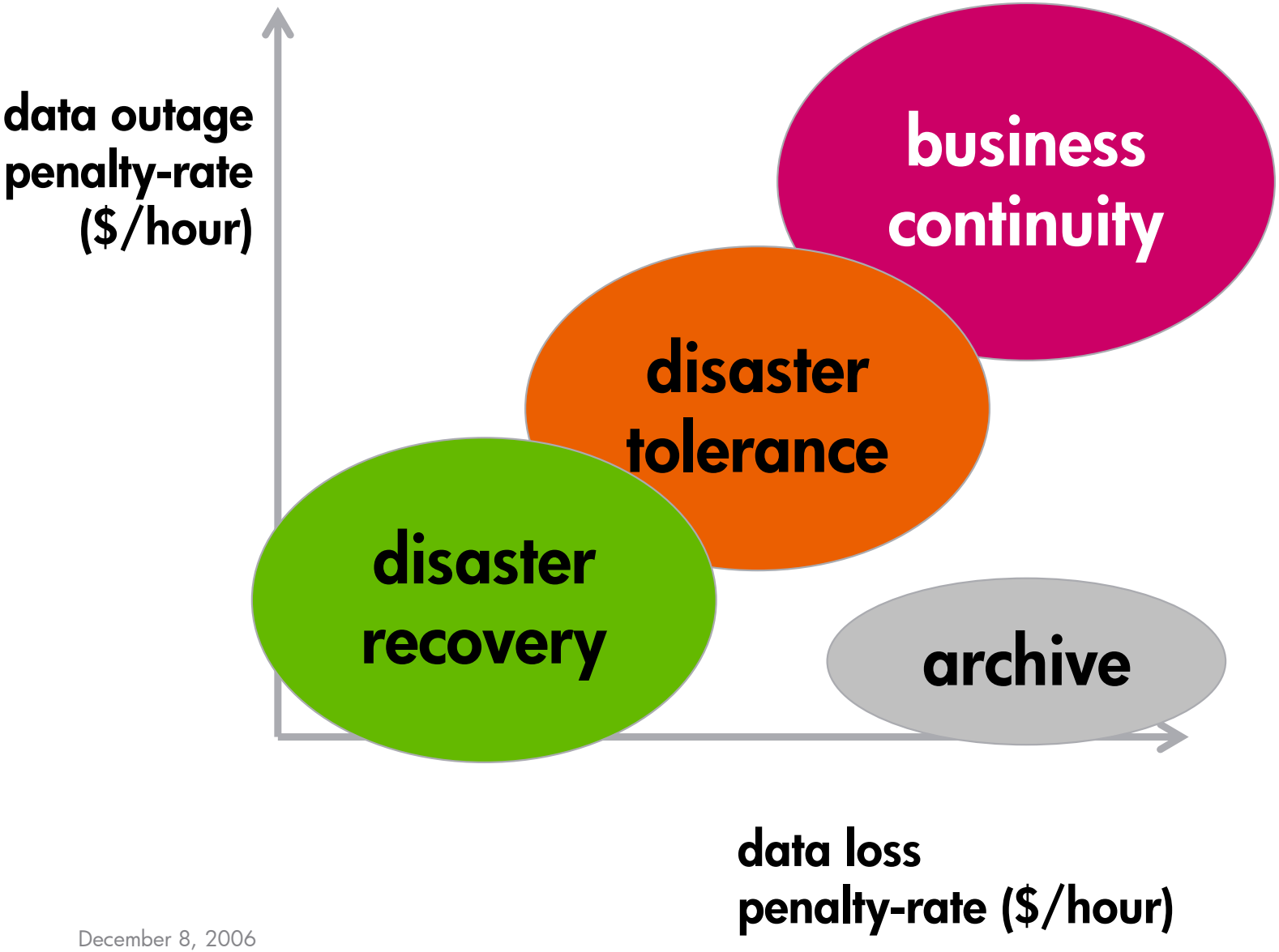


Management function: protect data

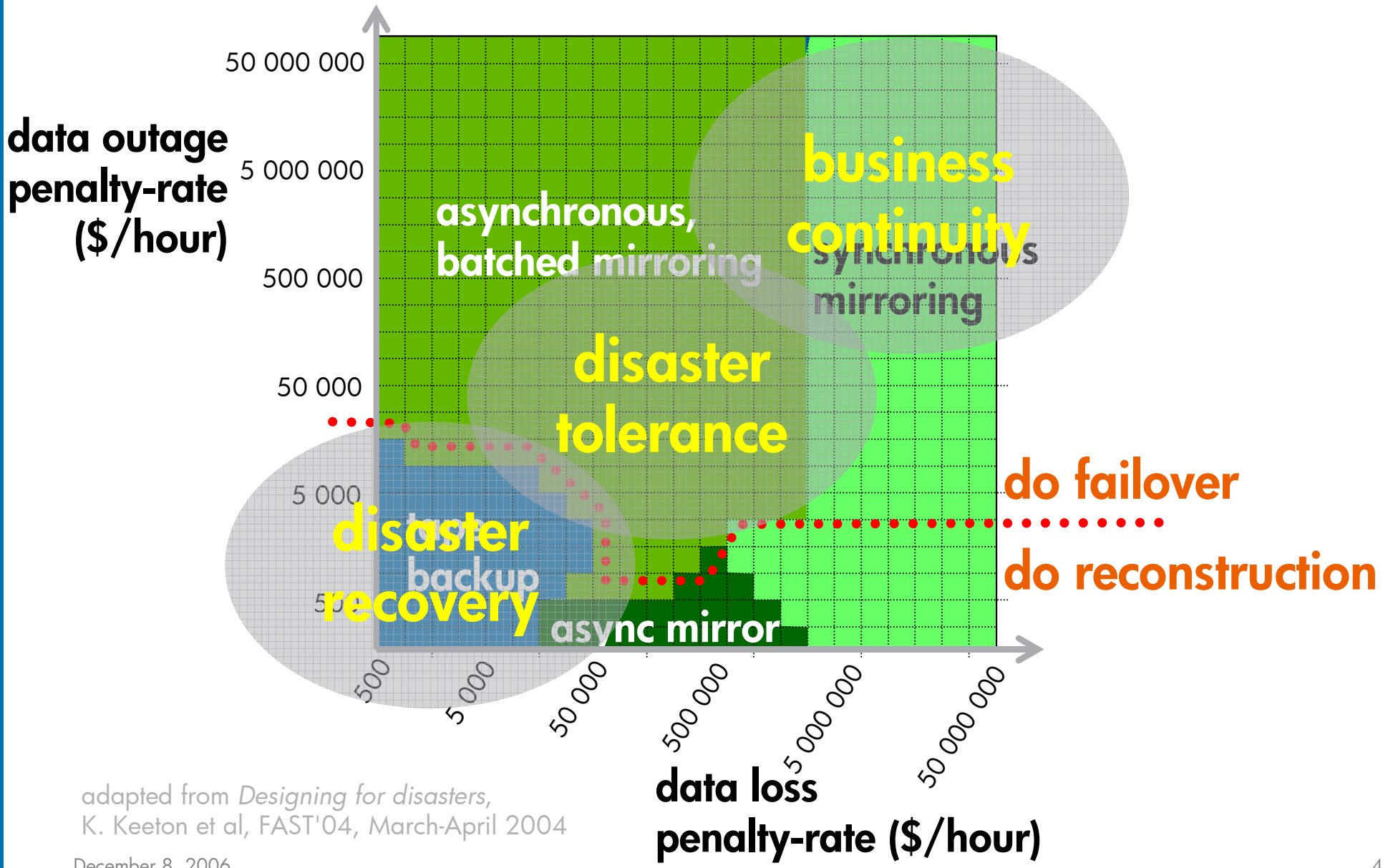
Anatomy of a failure



Management function: protect data
Goals defined by penalties



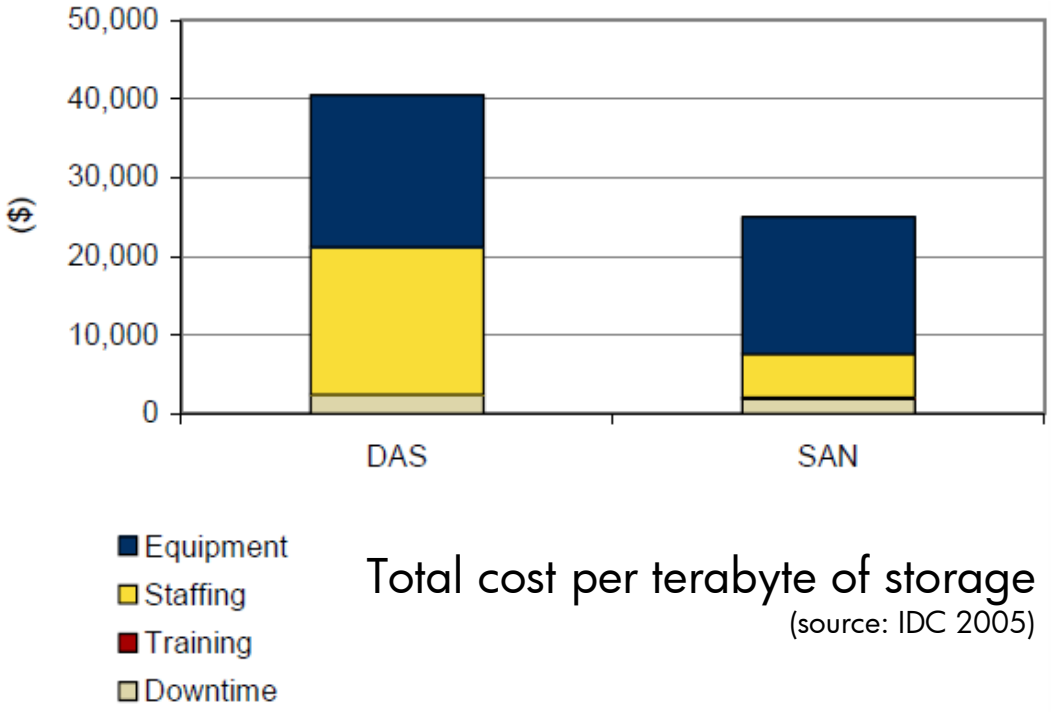
Management function: protect data
Automation simplifies choosing



adapted from *Designing for disasters*, K. Keeton et al, FAST'04, March-April 2004

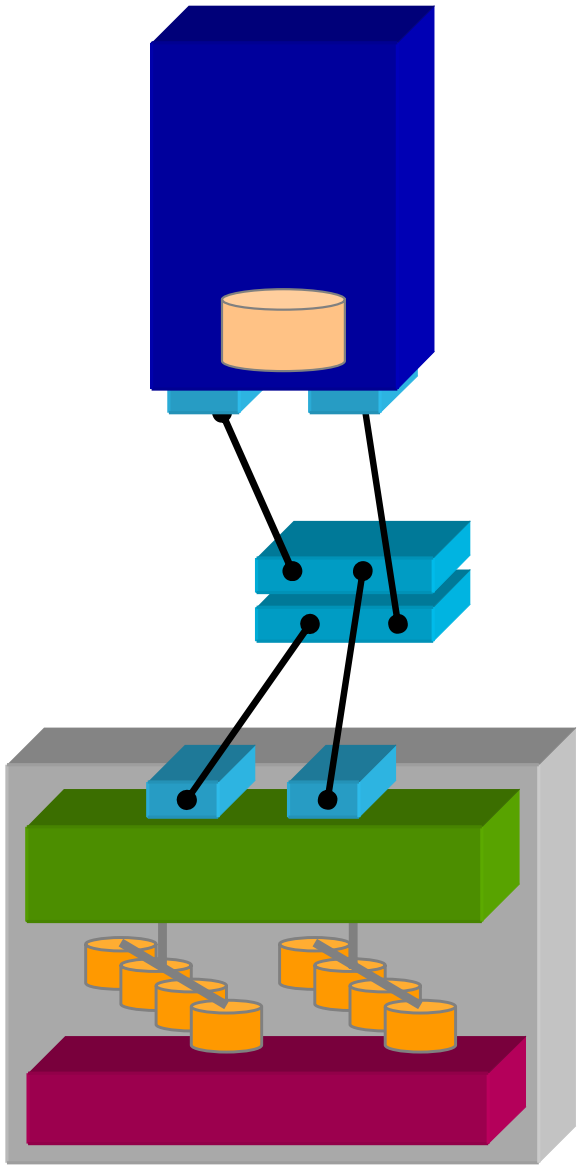
Storage-management challenges
Administrator costs

- Storage costs are dropping
  - 1995: ~$5000/GB raw
  - 2005: $0.5/GB raw
- Administrator costs are not
  - 2004–5 salary: $68k



Total cost per terabyte of storage
(source: IDC 2005)

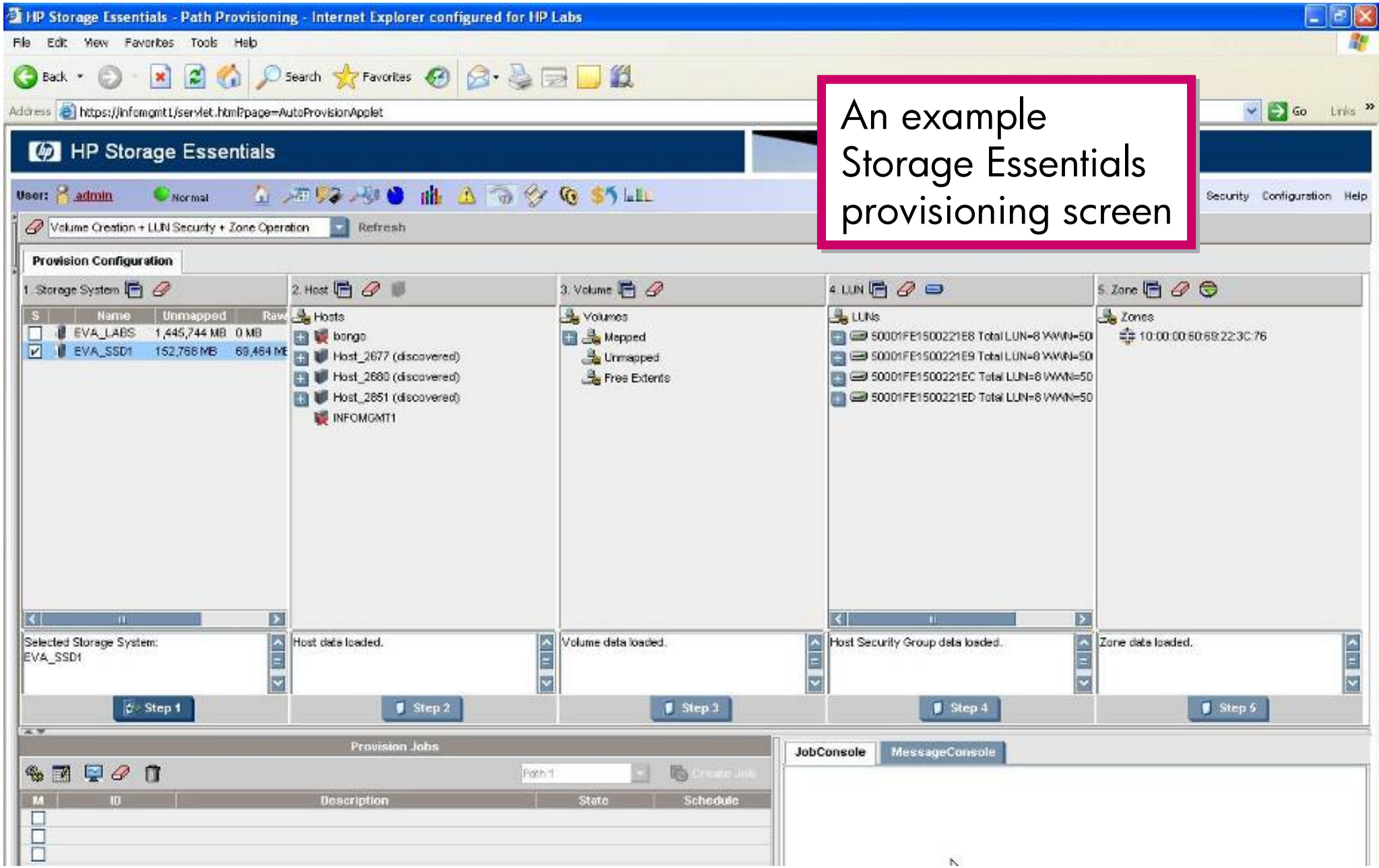
Storage-management challenges
Add a block-volume to a host



Touch points

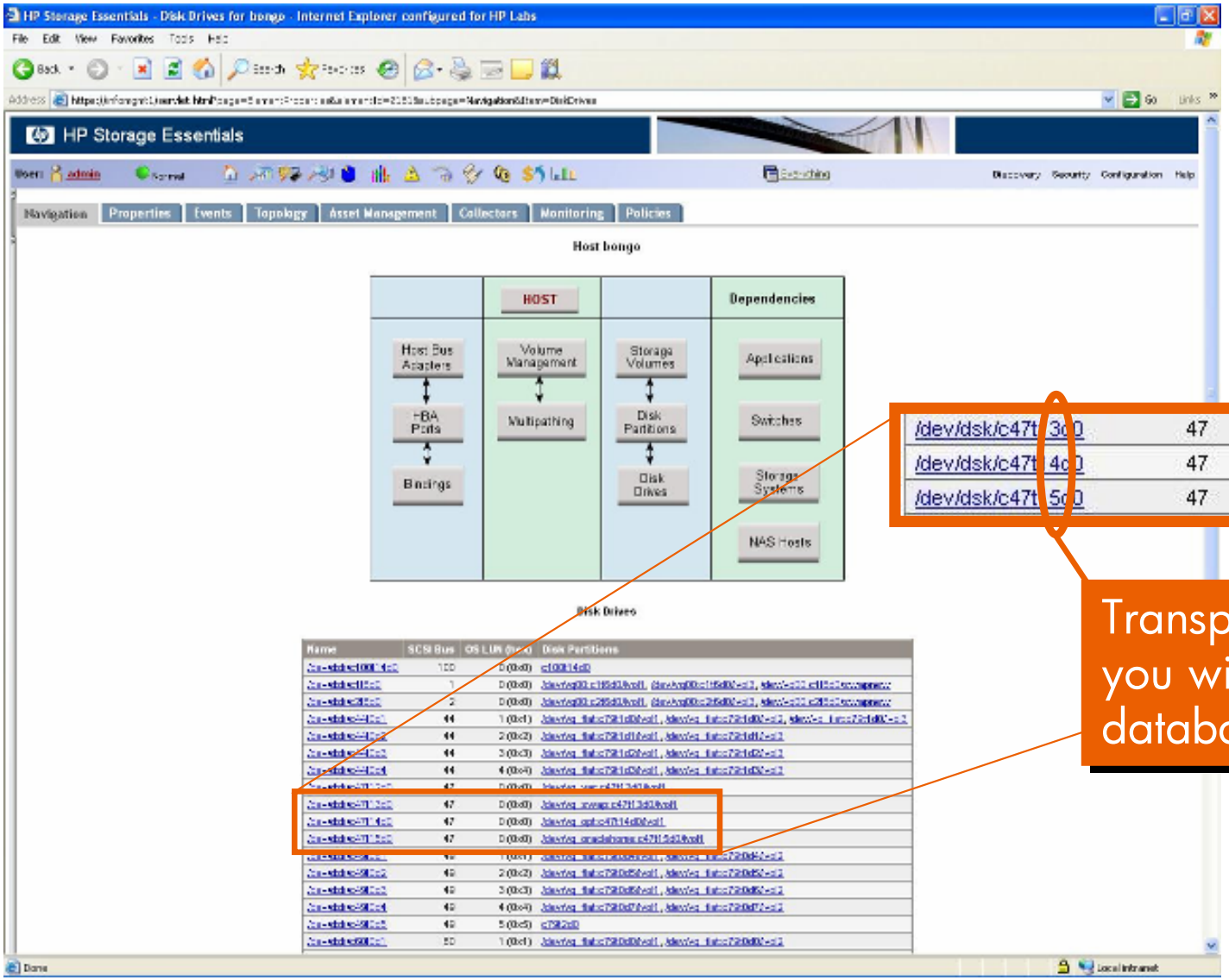
- logical volume manager
- storage-network interface cards
- storage network switches (zones)
- disk array ports (LUNs)
- logical unit (LU)
- physical volume usage

Storage-management challenges
Modern tools help …



An example Storage Essentials provisioning screen

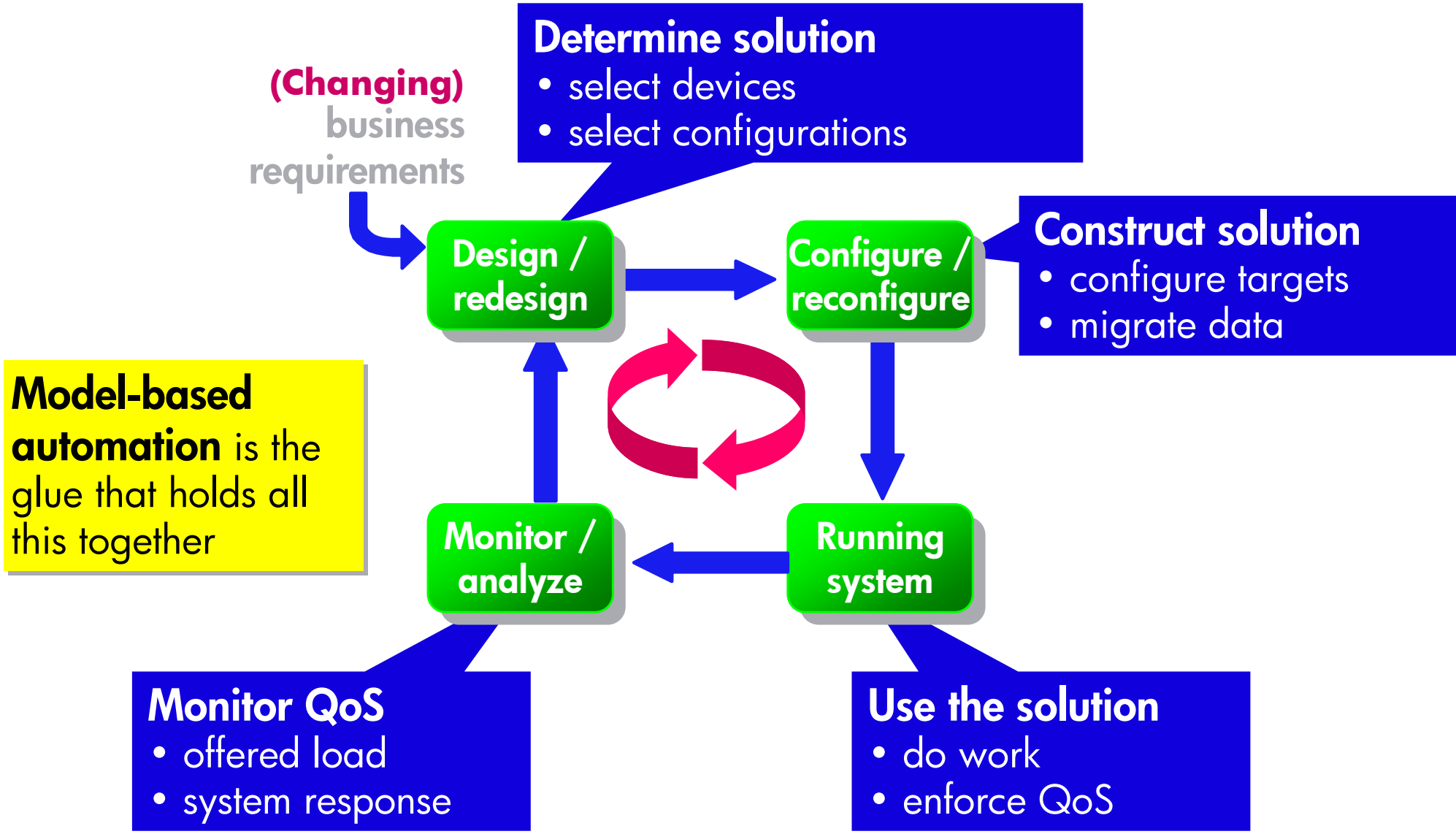
Storage-management challenges
… but finicky details still remain

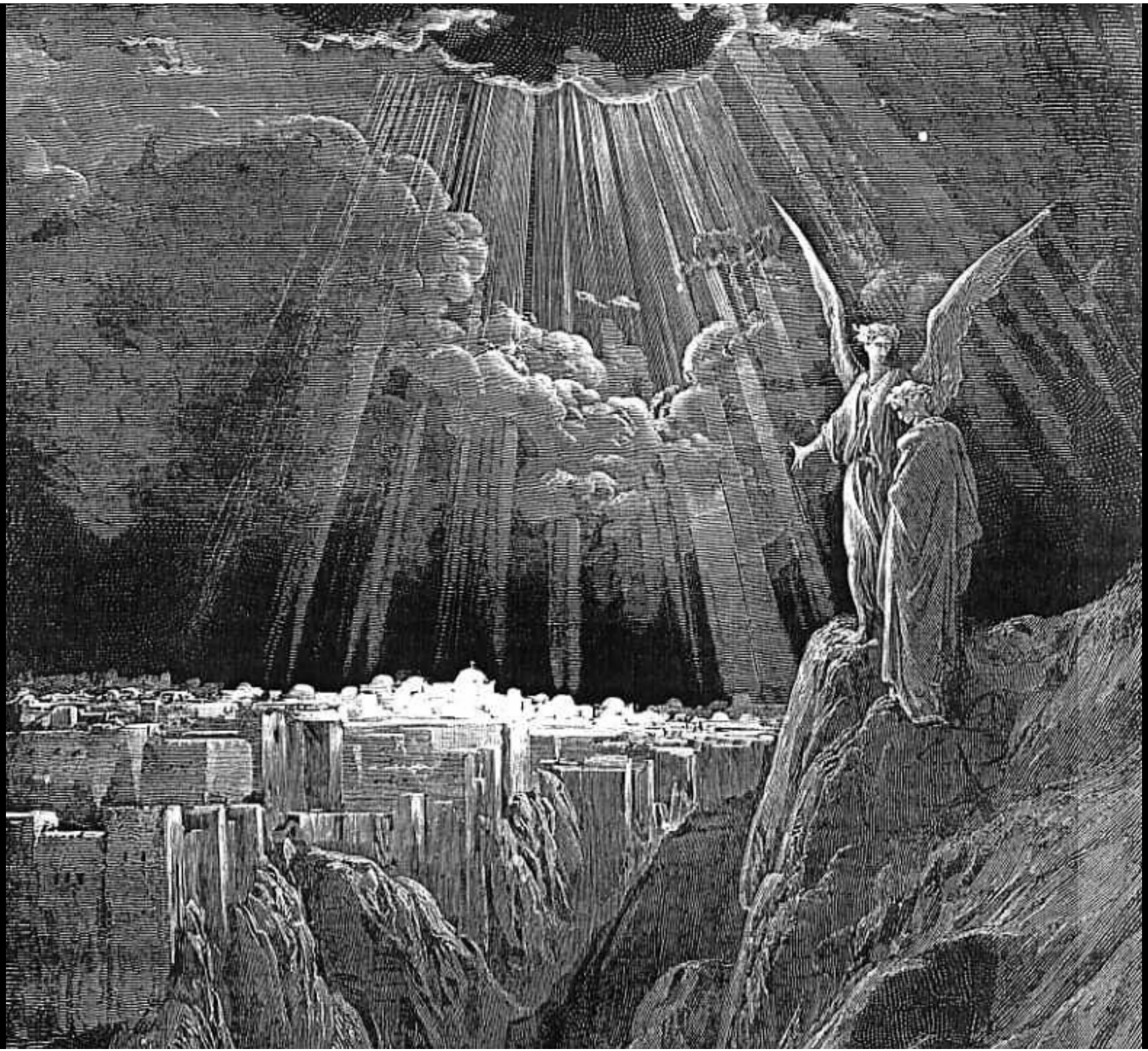


/dev/dsk/c47t13d0	47	0 (0x0)	/dev/vg_swap:c47t13d0/lvol1
/dev/dsk/c47t14d0	47	0 (0x0)	/dev/vg_opt:c47t14d0/lvol1
/dev/dsk/c47t15d0	47	0 (0x0)	/dev/vg_oraclehome:c47t15d0/lvol1

Transpose one digit, and you wipe out the Oracle database software!

Storage-management challenges
Solution: automation

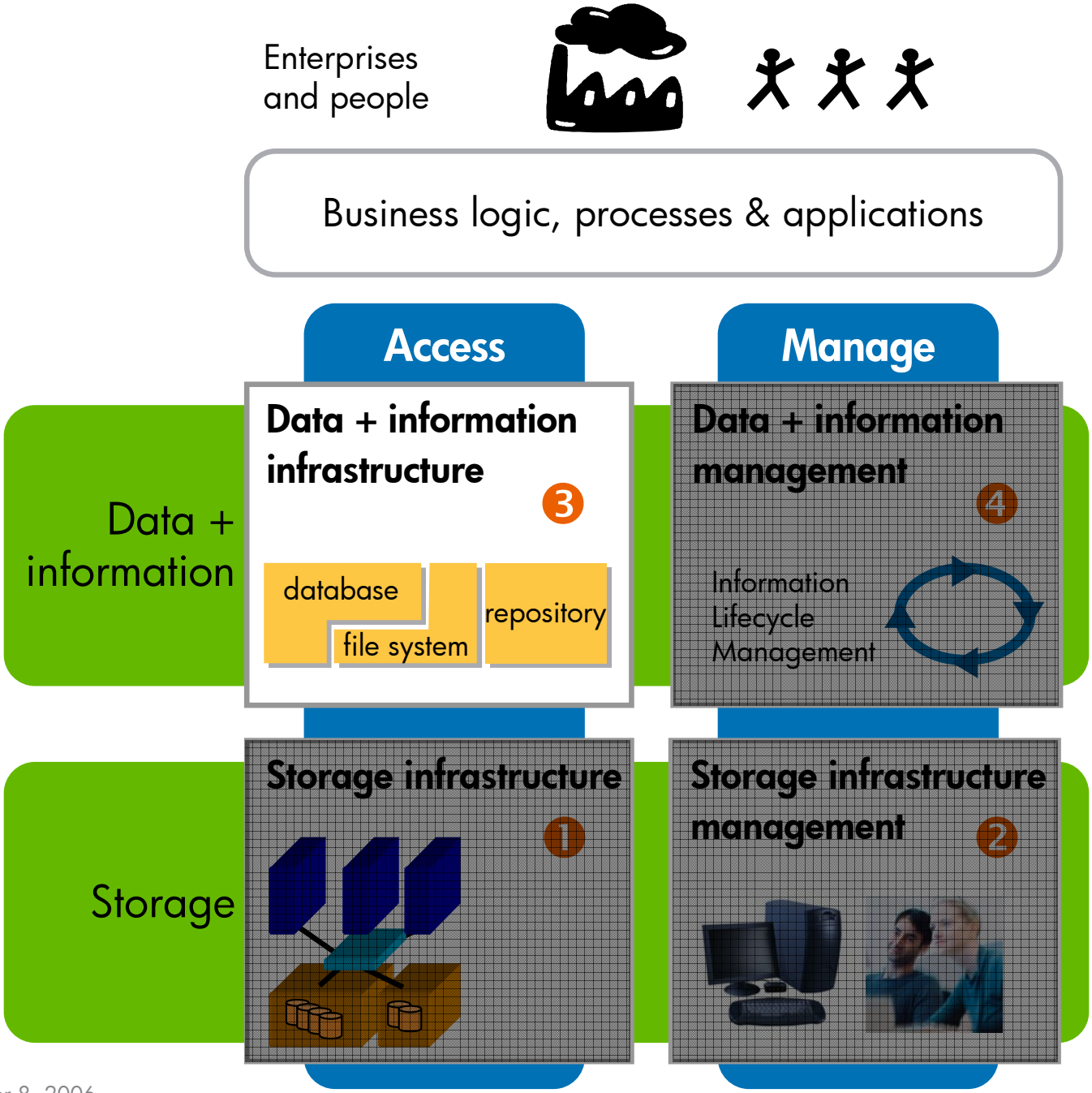




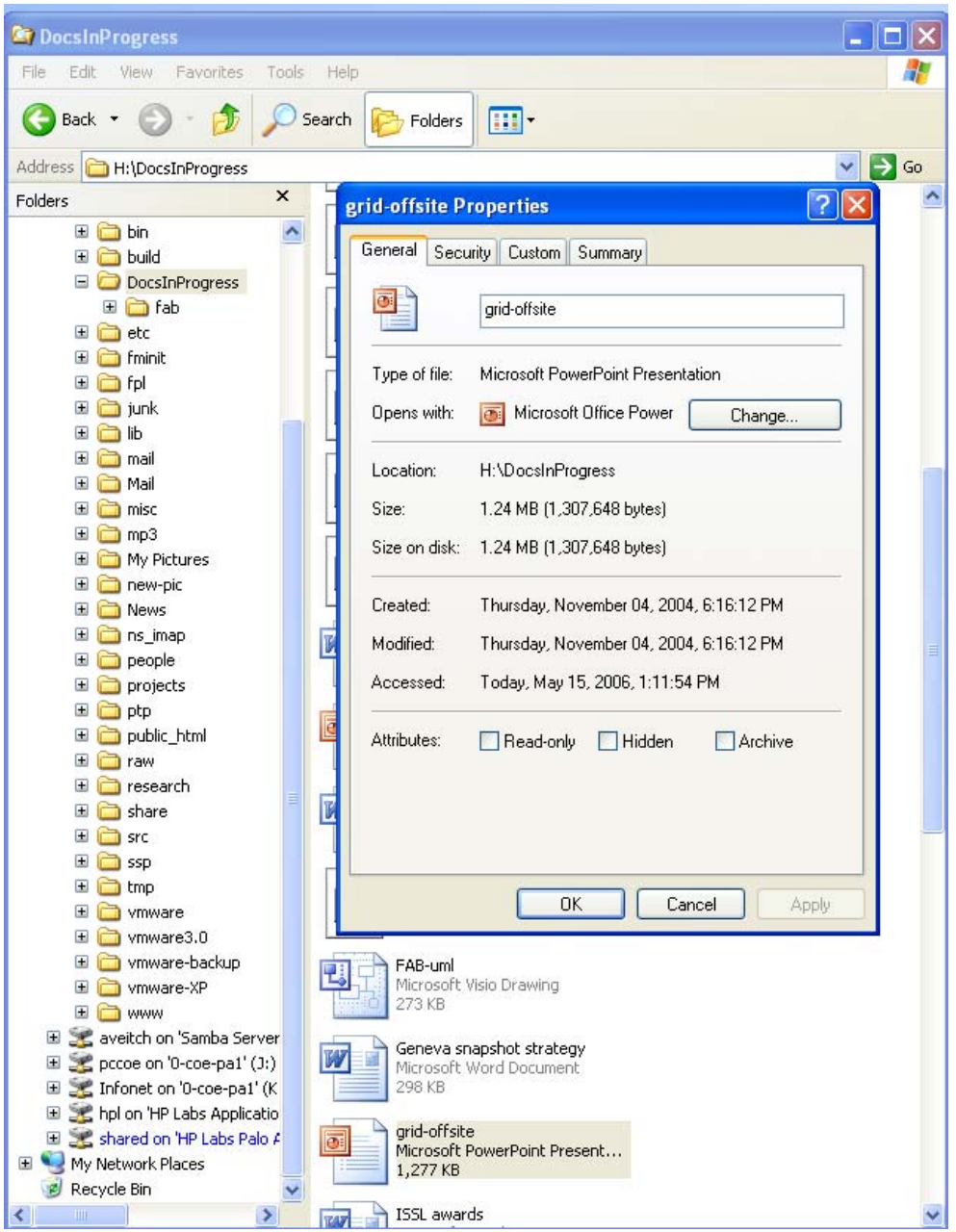
Storage infrastructure management: summary

- storage management appears complicated, because it **is complicated**
- monitoring is pretty much under control; **control** is next
  - example: data replication
- **automation** is the key to making IT business-effective
  - *virtualization* makes this simpler

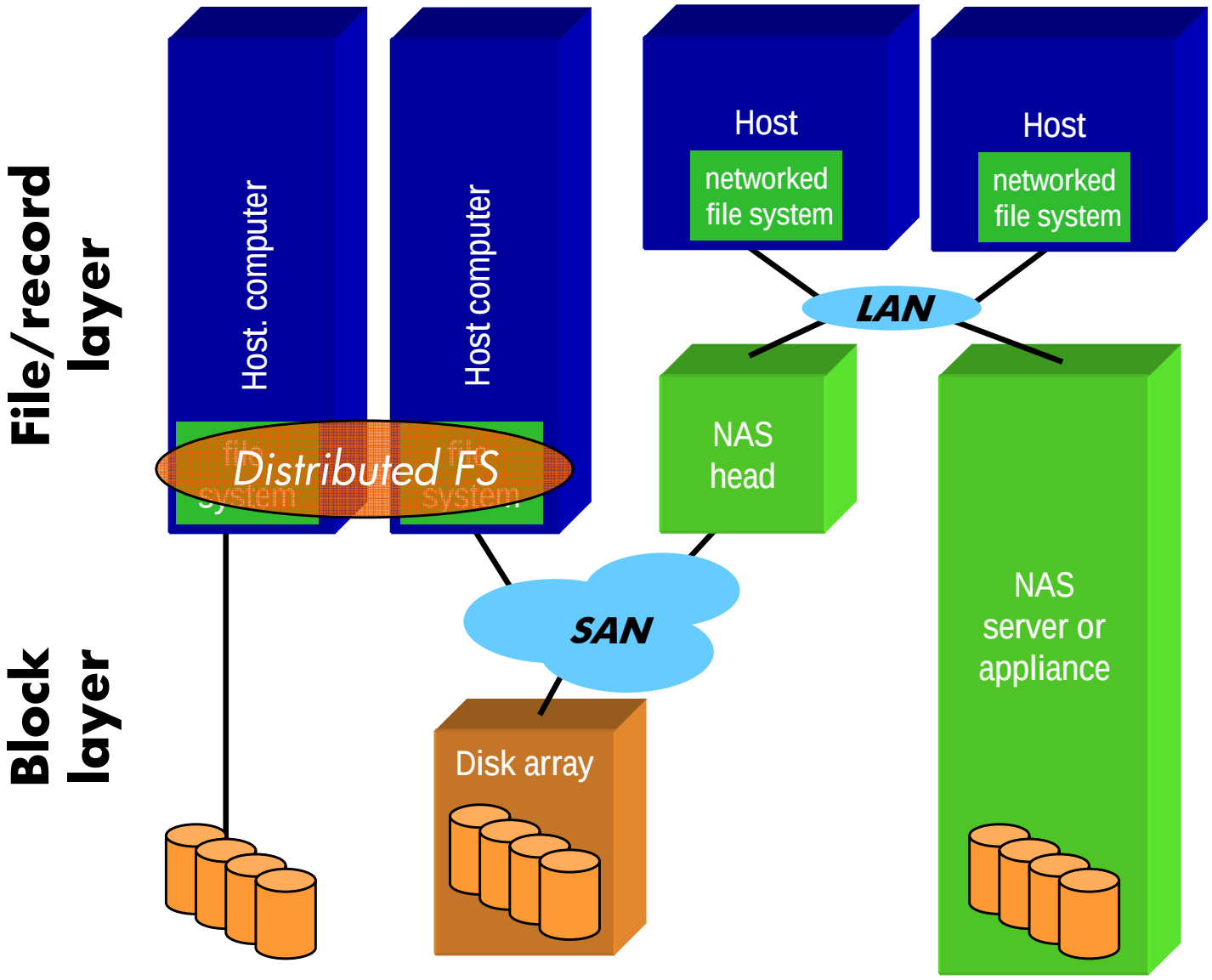
Data/info infrastructure



File systems



File systems and NAS



SAN (Storage Area Network)

LAN (Local Area Network)

NAS (Networked Attach Storage)

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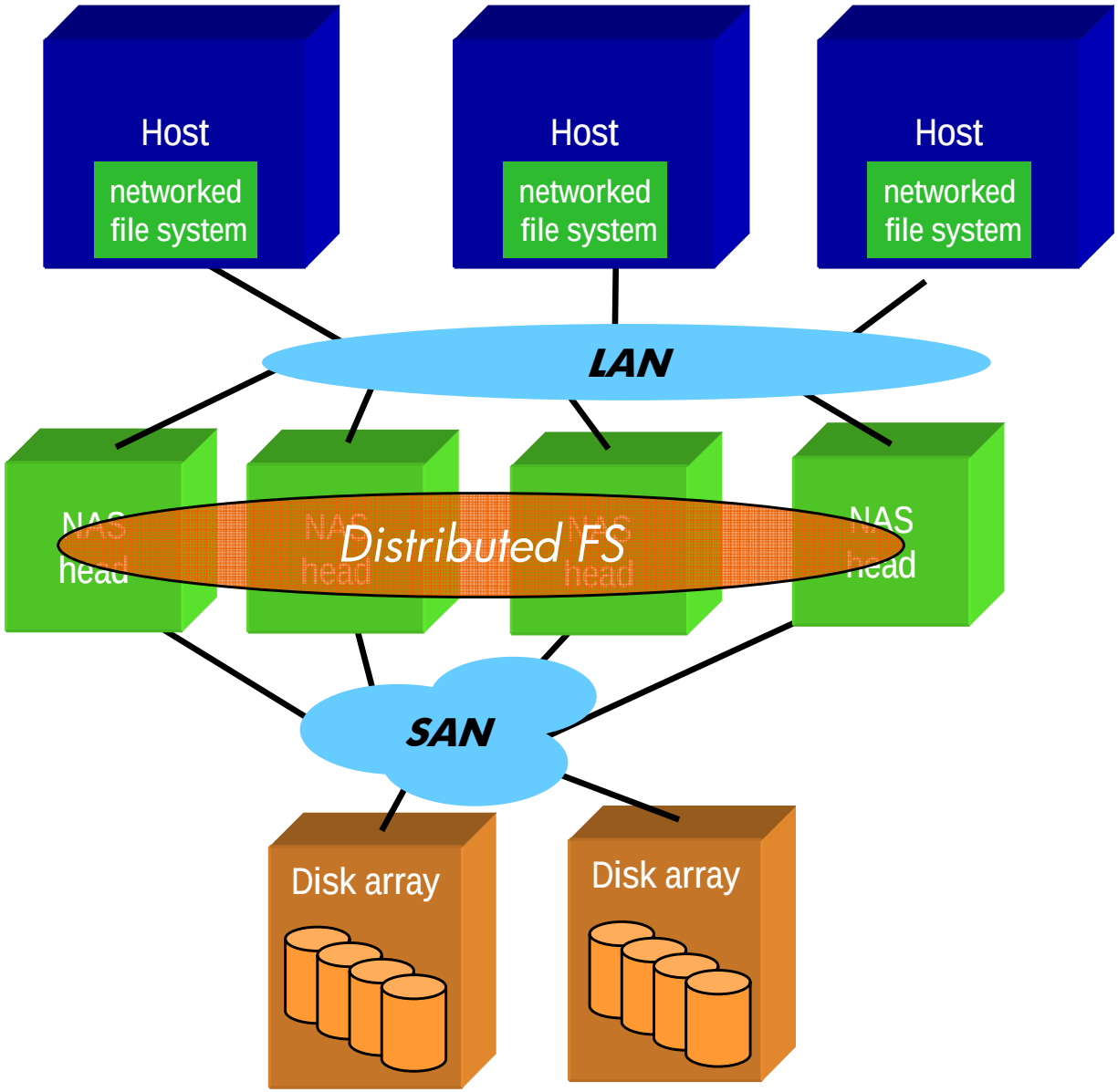
Clustered NAS (1)



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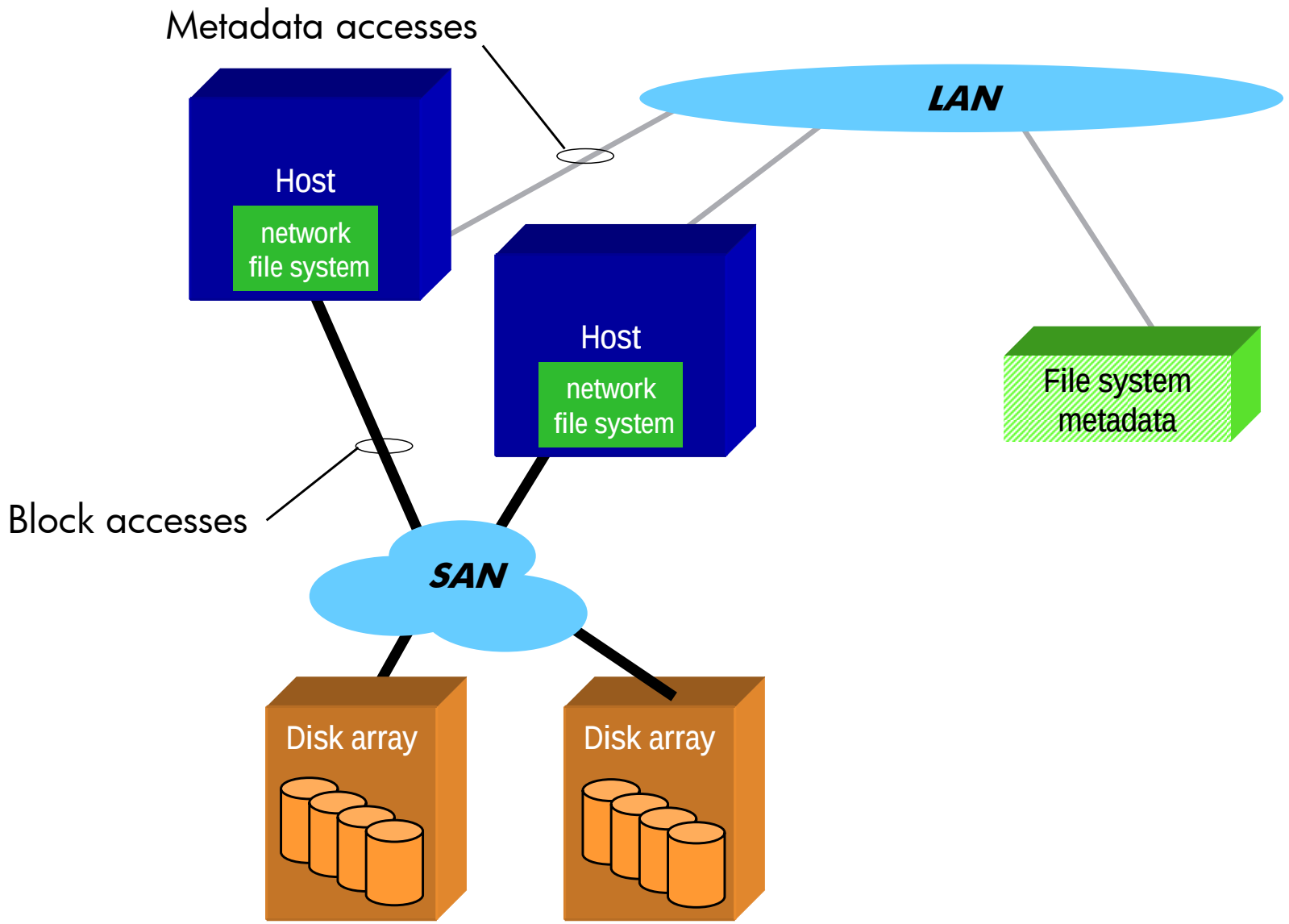
Clustered NAS (2)



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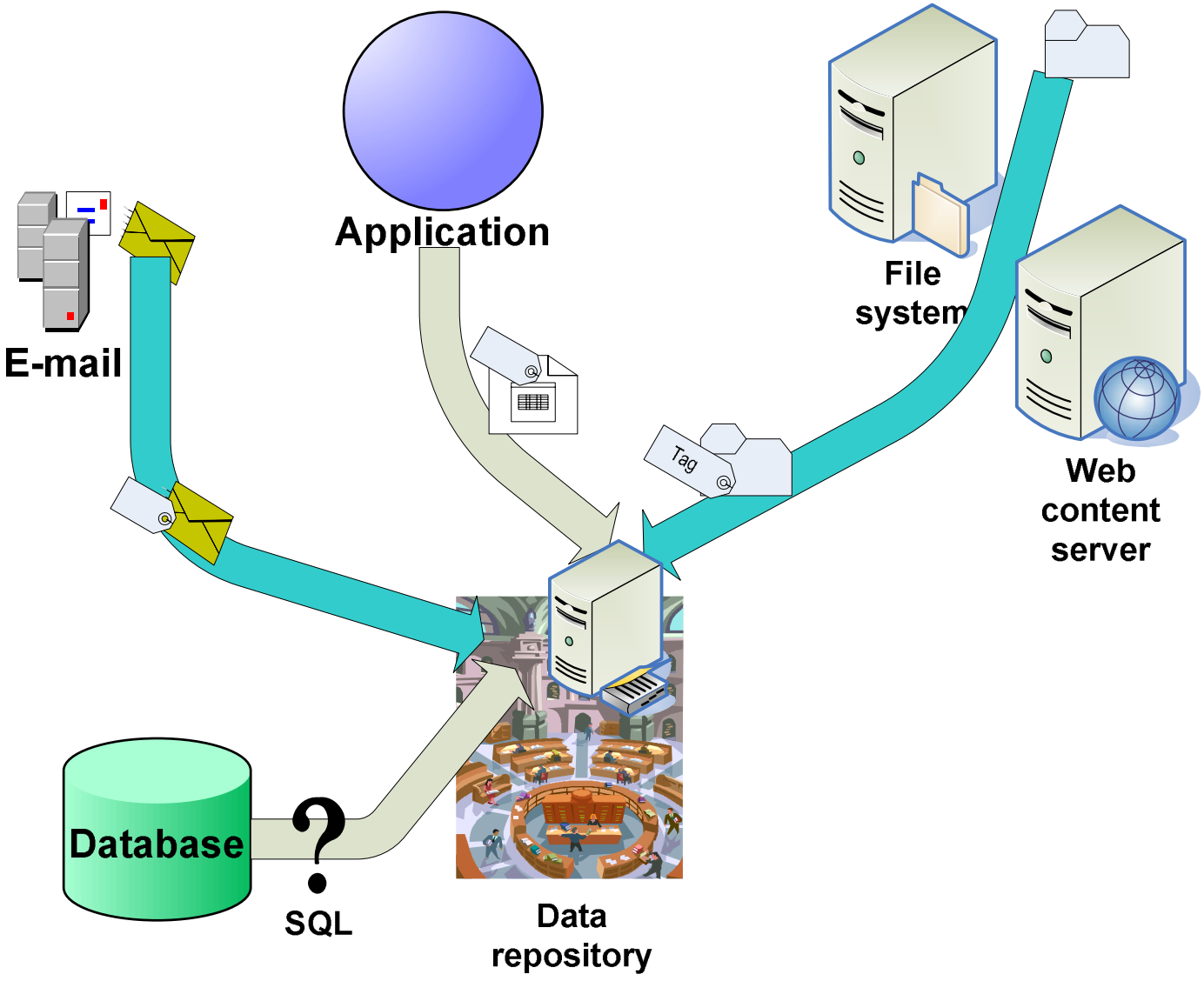
Databases

employee table

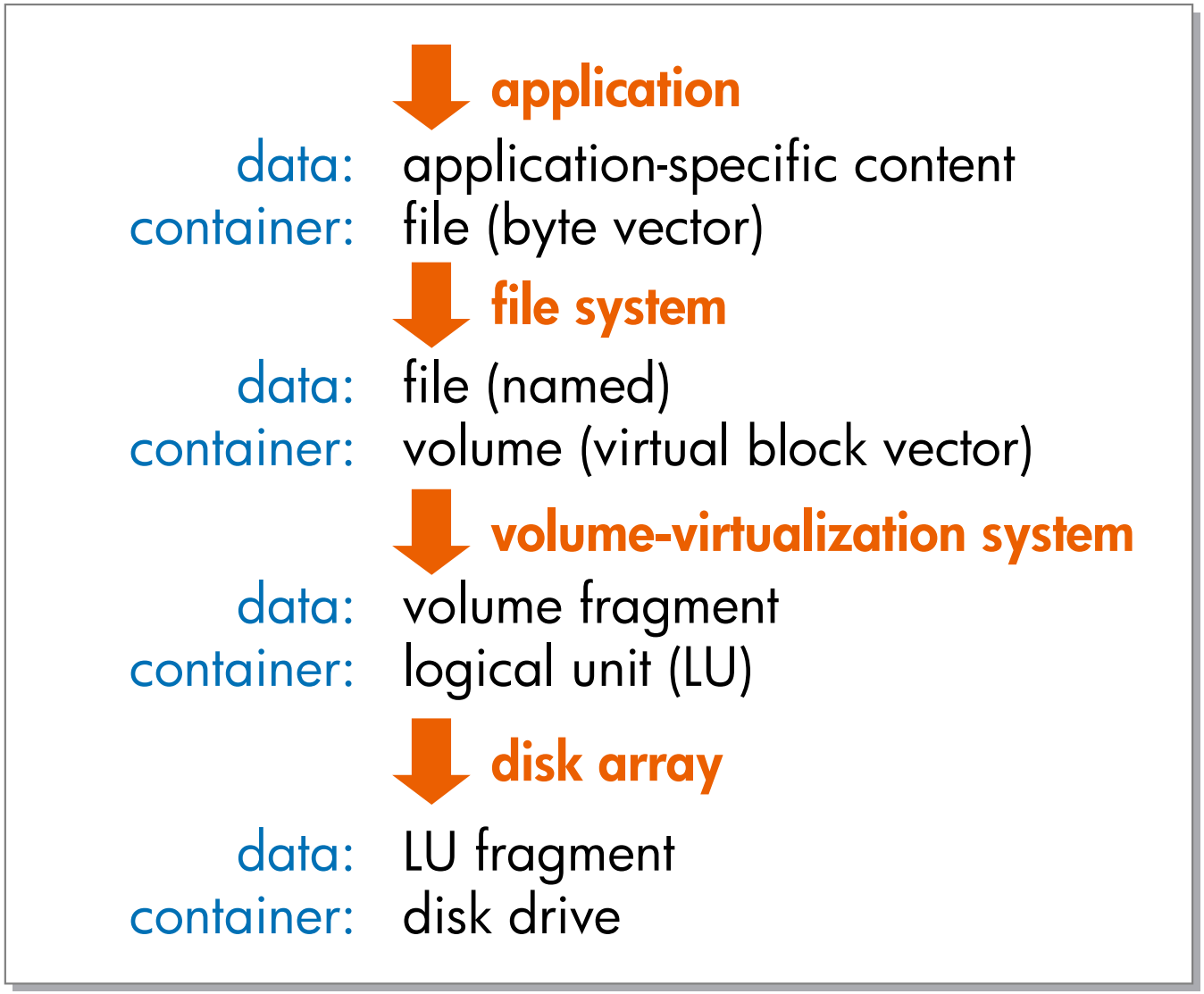
Public	John	Q	12789	123-45-6789	$5,000
Doe	Jane	P	34939	234-56-7890	$7,500
Flintstone	Fred	R	00212	345-67-8901	$2,789
Rubble	Barney	F	00314	456-78-9102	$3,012
Coyote	Wile	A	15715	567-89-0123	$12,000
Runner	Road	A	15714	678-90-1234	$12,001

Repositories

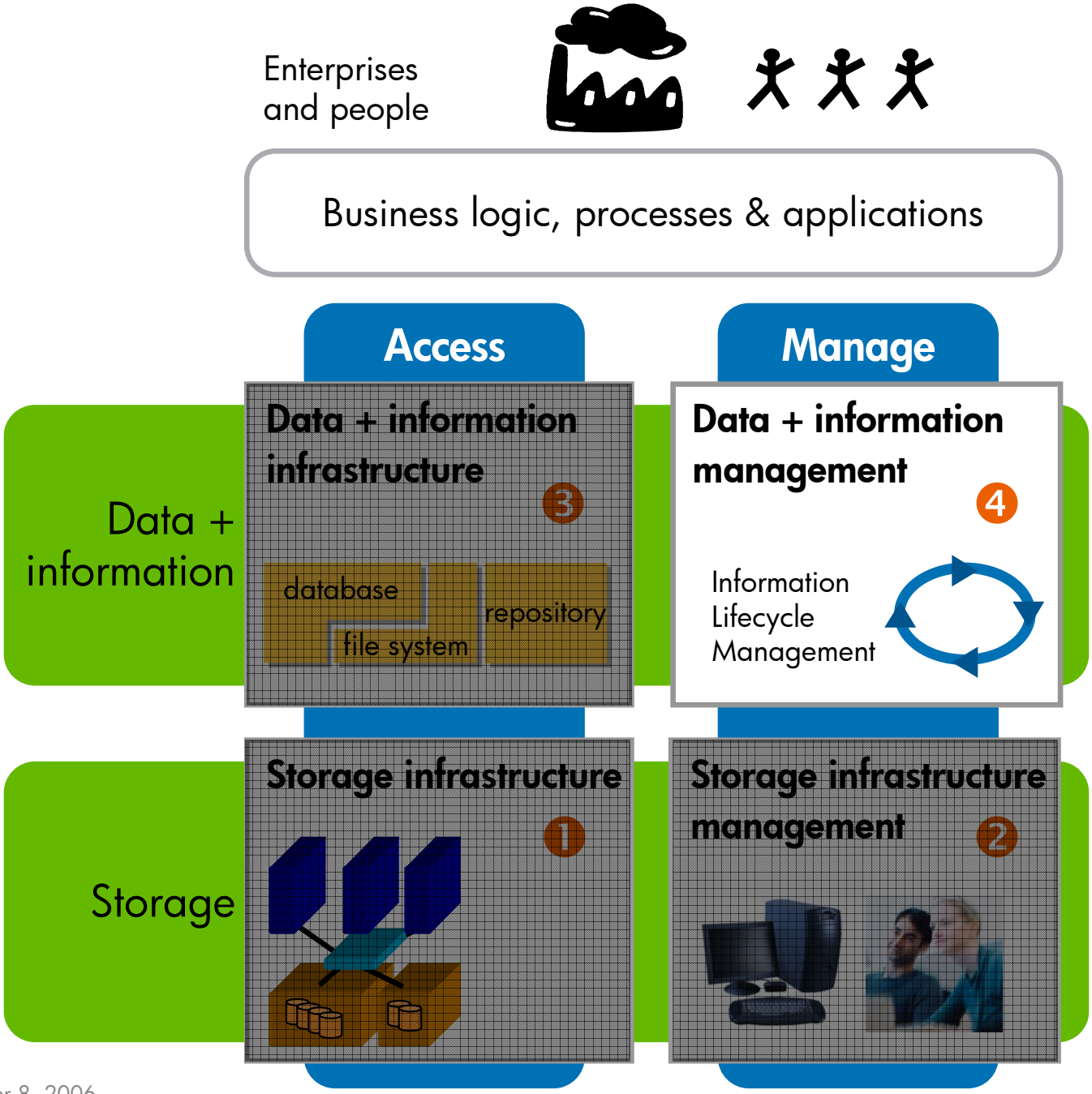


Data and information infrastructure

Contents and containers



Data/info infrastructure management



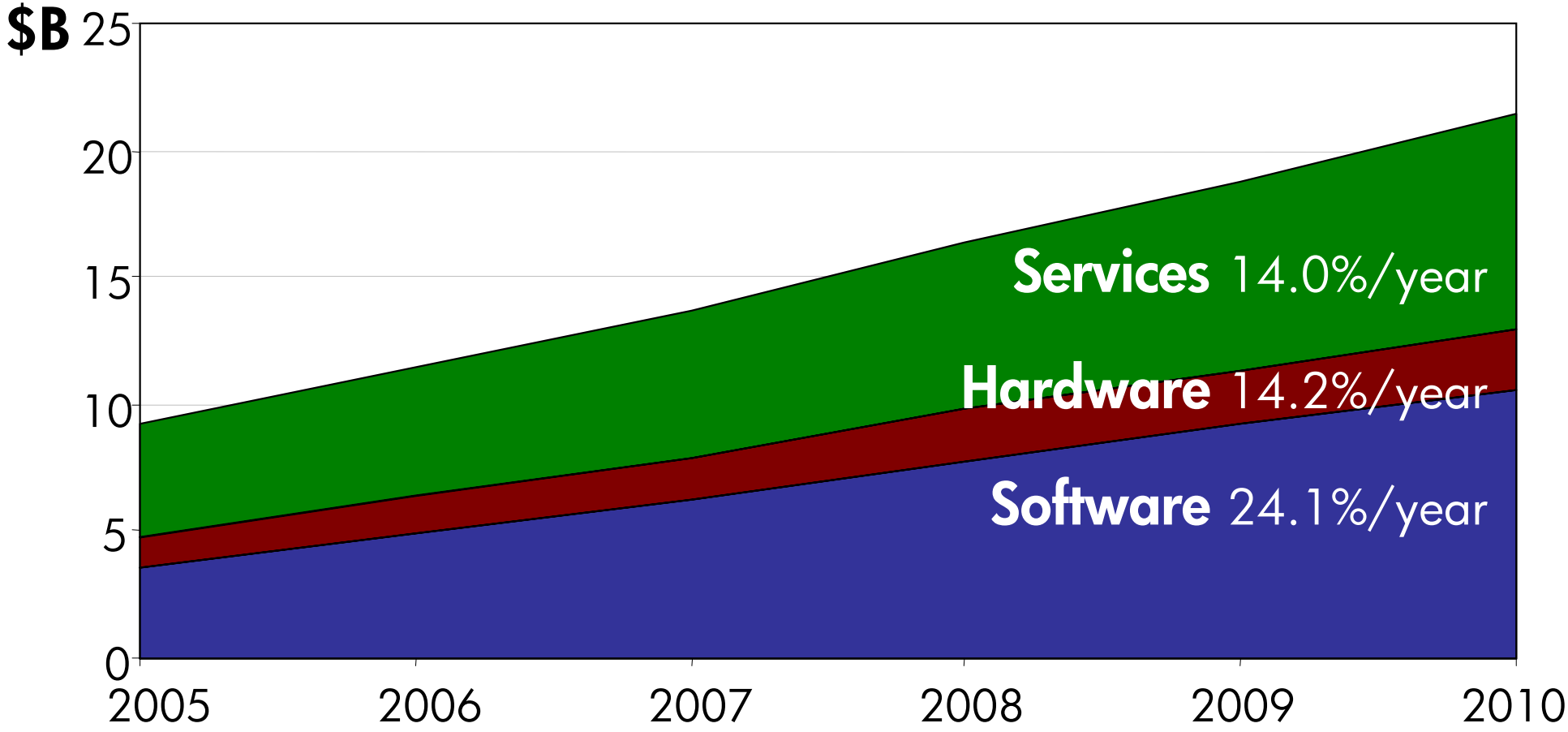
Information Lifecycle Management (ILM)

- What to keep
- How long to keep it
- Where to keep it

- Drivers:
  - value of information
  - law/regulations (compliance)
  - security & privacy needs

Information-management market size

worldwide compliance-driven info-management revenue



source: IDC, 2006.

A typical information lifecycle: unstructured data

Operational

- frequently updated during 72 hours after creation

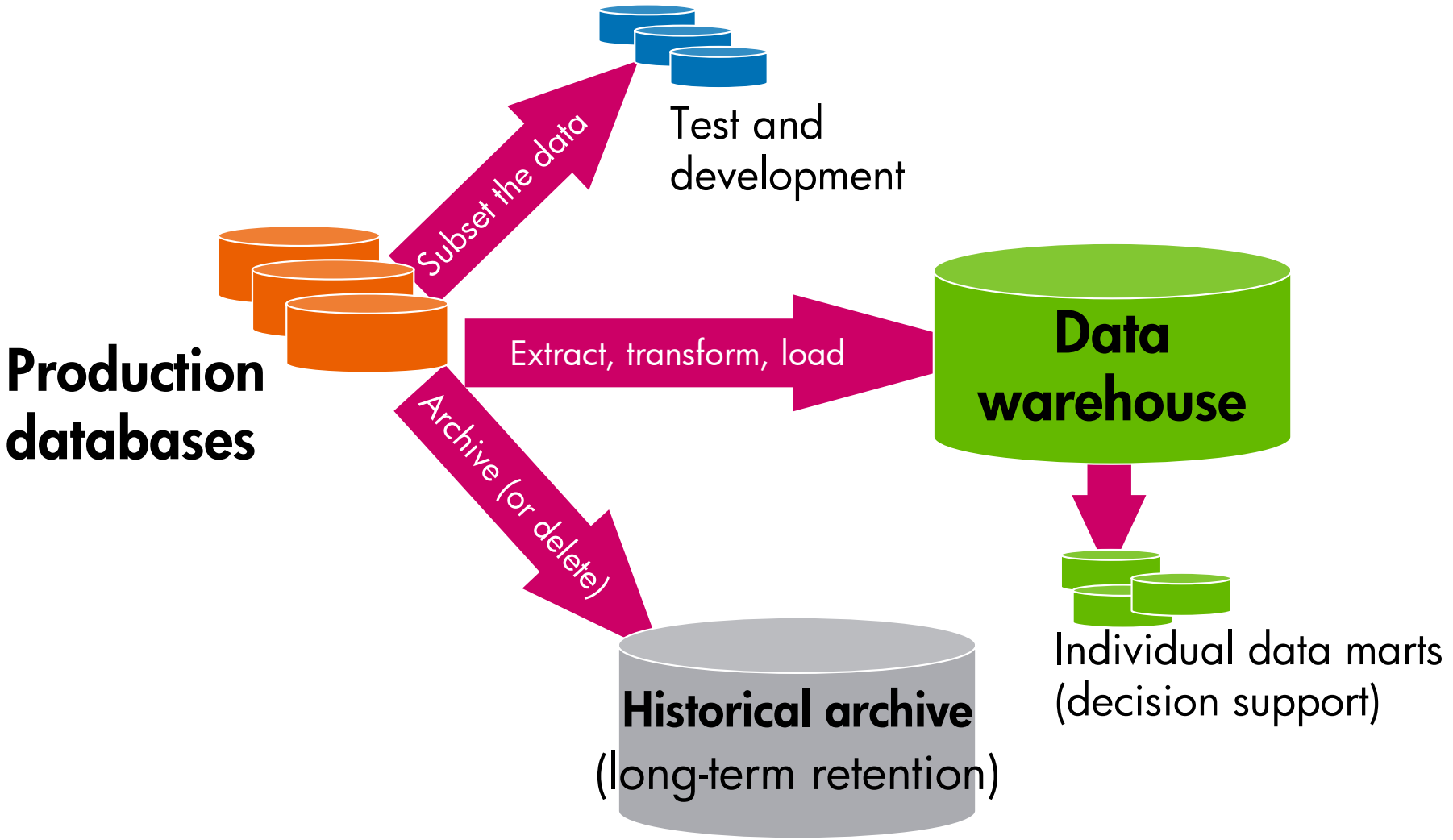
Transitional

- infrequently updated
- converted to business record format

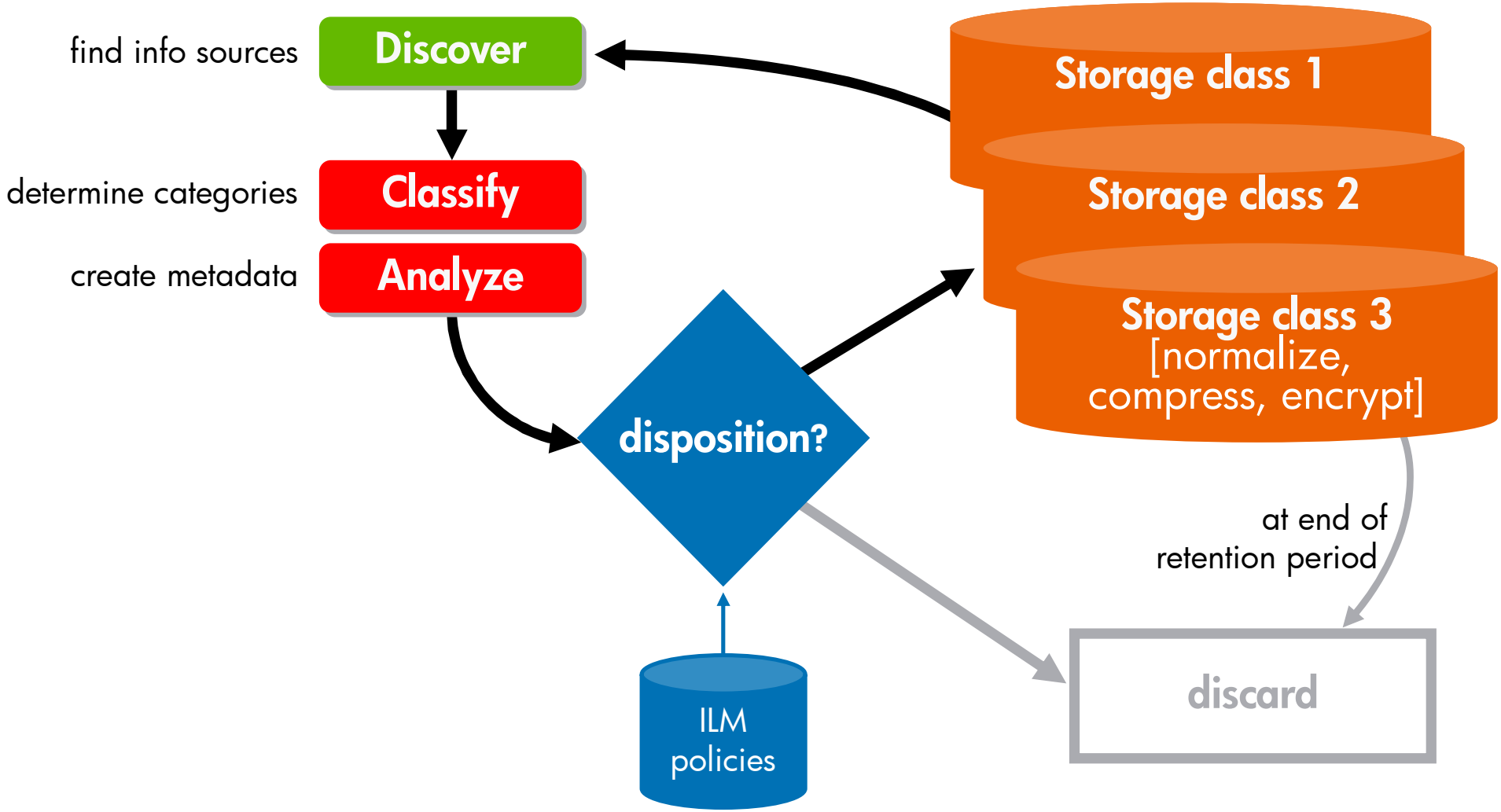
Archival

- static (rarely accessed)
- subject to long-term records management

Lifecycles are not always linear … the case of structured data

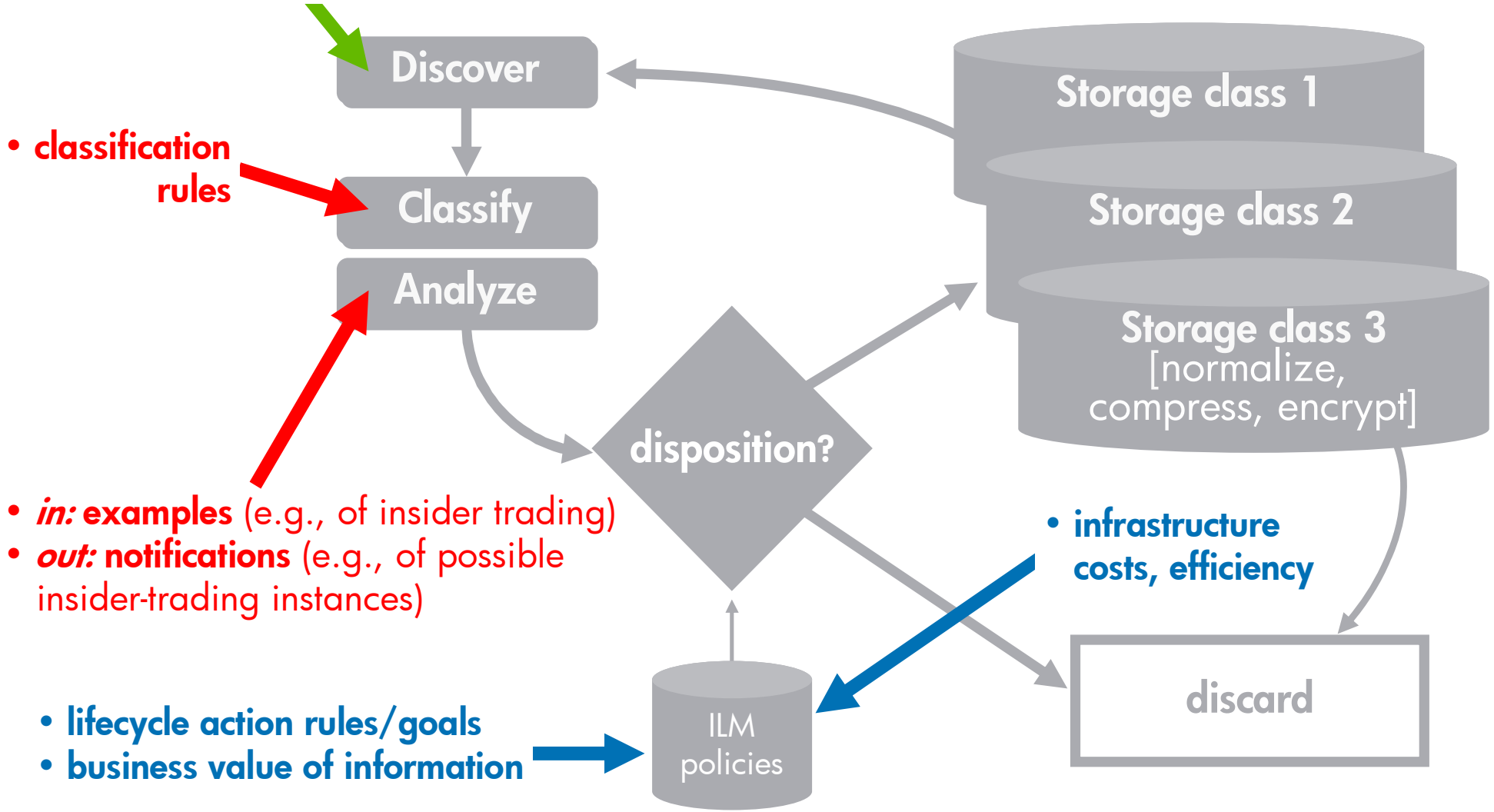


ILM processing functions



ILM processing functions

- *in:* business-process info needs
- *out:* information-quality metrics



- classification rules

- *in:* **examples** (e.g., of insider trading)
- *out:* **notifications** (e.g., of possible insider-trading instances)

- infrastructure costs, efficiency

- lifecycle action rules/goals
- business value of information

ILM adjacencies

Business-process management

using information for business management

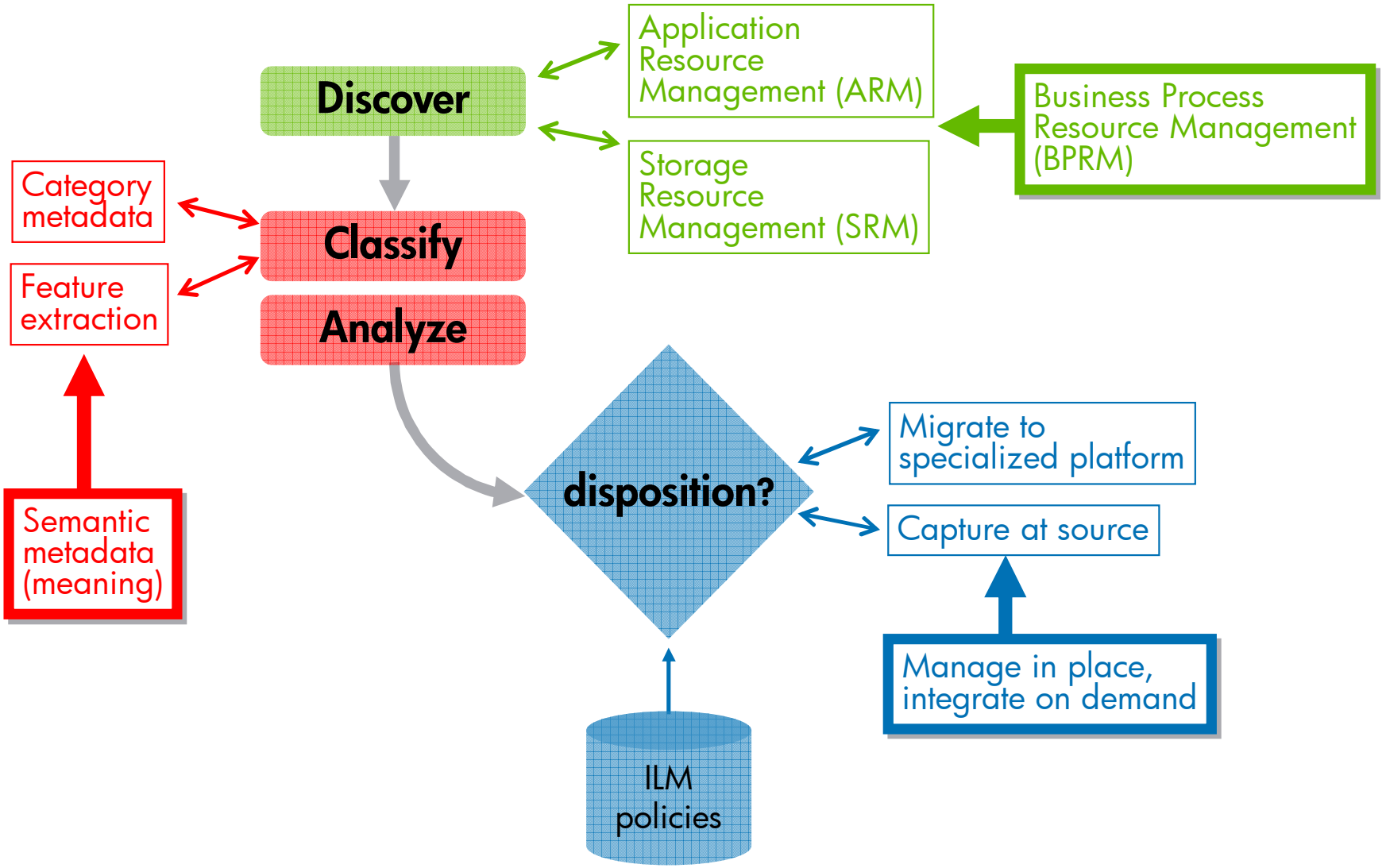
Information semantics

what information means

Information integration

across multiple sources

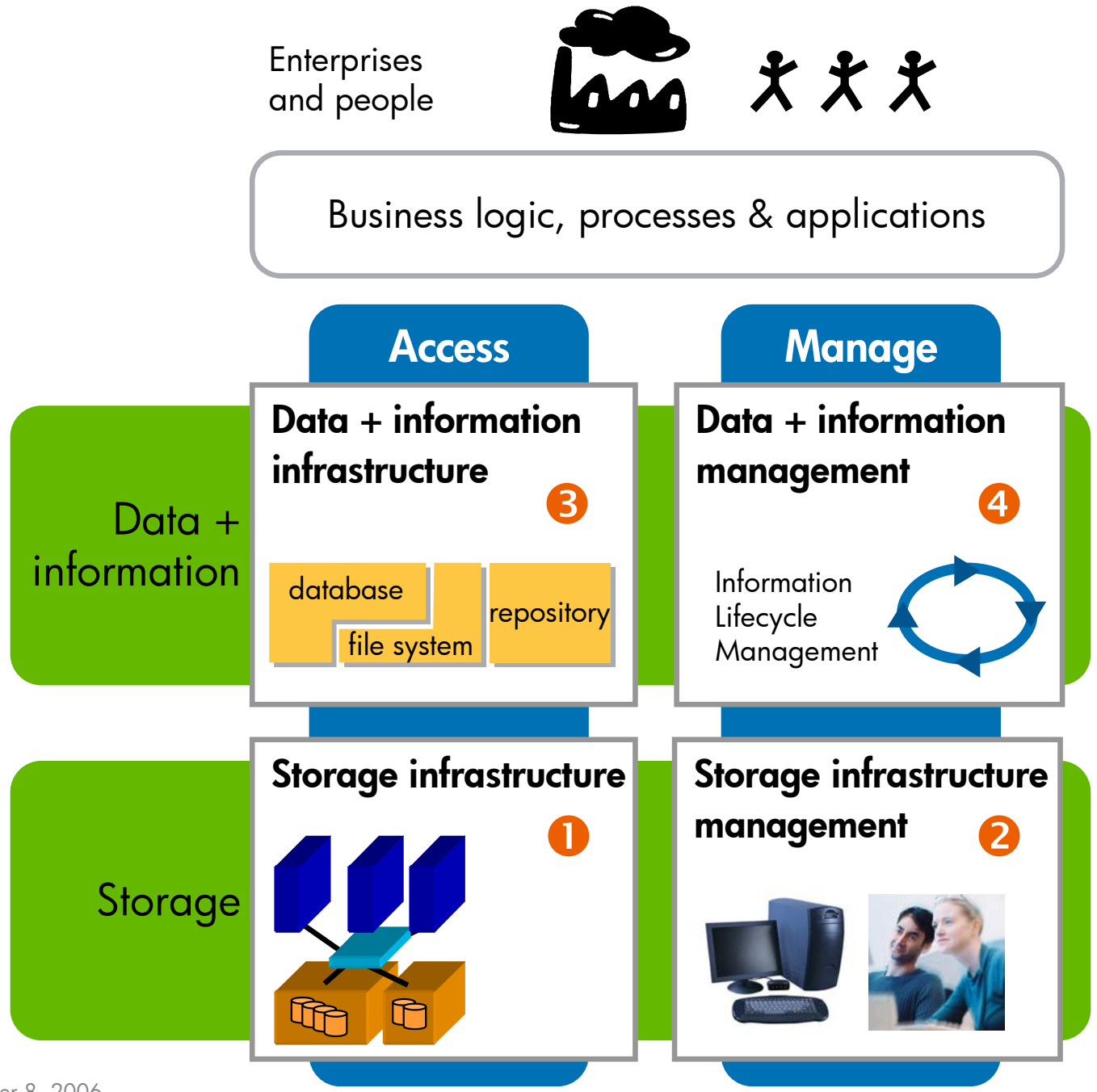
ILM adjacencies (2)



Key messages about data/information management

- ILM helps align information management goals with business objectives
- today: a compliance-driven market today
- tomorrow: opened up by understanding of data contents

Summary


Enterprises and people
Business logic, processes & applications
Access
Manage
Data + information
Data + information infrastructure
3
database
file system
repository
Data + information management
4
Information Lifecycle Management
Storage
Storage infrastructure
1
Storage infrastructure management
2

invent