CASTOR Tutorial

Part 1
Introduction and overview

Outline

- CASTOR2 context
  - Scope and constraints
  - History
    - SHIFT, CASTOR 1
  - Requirements
- CASTOR 2 architecture overview
  - blocks and components
  - and their status
- Technology choices
  - about languages
  - UML and the code generation
  - DB centric

DM

Outline

CERN IT Department

- CASTOR2 context
  - Scope and constraints
  - History
    - SHIFT, CASTOR 1
  - Requirements
- CASTOR 2 architecture overview
  - blocks and components
  - and their status
- Technology choices
  - about languages
  - UML and the code generation
  - DB centric

Scope and constraints

- Provide a managed storage service for all physics data at CERN
  - Transparent tape media management
  - Automated disk cache management
  - Unique global name space
- Assure that CERN can fulfill the Tier-0 and Tier-1 storage requirements for the LHC experiments
  - Central Data Recording (CDR)
  - Data reconstruction
  - Data export to Tier-1 centers
- Strive to meet the CERN Tier-3 requirements
  - The exact requirements and scale are unknown
  - CASTOR should support the CERN analysis
    - xrootd integration
- CASTOR2 assumes big data stores
  - Not designed to work for Tier-2 institutes

SHIFT

- **S**calable **H**eterogeneous **I**ntegrated **F**acili**T**y
  - Started as a project (HOPE) between the OPAL experiment and the CN division in early 90’s
  - Main authors: Jean-Philippe Baud, Fabrizio Cane, Frederic Hemmer, Eric Jagel, Ashok Kumar, Gordon Lee, Les Robertson, Ben Segal, Antoine Trannoy
- All user file access on disk. No direct tape access
  - The idea of tape staging at CERN dates back to the early 70’s
- Components
  - Stager daemon (stgdaemon) managing the disk pool
  - Remote Tape Copy (RTCOPY)
  - Remote File IO (RFIO)
  - Tape allocation and control (tpdaemon)
    - Label processing, load, unload, positioning
    - Operator interface for manual mounting
    - Interface to robotic mounting
  - Tape Management System (TMS)
    - Logical volume repository
- Users access files by Tape volume (VID) + tape file sequence number (FSEQ) → flat namespace: stagein –V EK1234 –q 35 …
  - The experiments normally had their own catalogue on top (e.g. FATMEN)

- CERN was awarded the 21st Century Achievement Award by Computerworld in 2001

DM

SHIFT limitations

CERN IT Department

- Data rate: more than 10MB/s per stream is difficult to achieve
- Stager catalog does not really scale over 10,000 files
- SHIFT does not support many concurrent accesses
- No automatic allocation of tapes
- No easy access to files by name without an external package
- automatic migration/recall of files is not available

Alternative solutions

- Since the mid-90’s CERN had been looking and testing alternative solutions to SHIFT
  - OSM
  - ADSM (now TSM):
  - HPSS
  - Eurostore
- Only HPSS was run in production for 3 years (1998 – 2001)

CASTOR1

- Cern Advanced STORage manager
  - Project started in 1999 to address the immediate needs (NA48, Compass) and provide a base that would scale to meet the LHC requirements
  - Managed storage: tapes hidden from the users
  - Main authors: Jean-Philippe Baud, Fabien Collin, Jean-Damien Durand, Olof Bärring
- Components
  - Stager daemon enhancements
    - Automatic tape migration added
  - Remote File IO (RFIO) supports data streaming
  - Volume Manager (VMGR) replaces TMS
  - Name server (Cns) provides a CASTOR name space
  - Tape Volume and Drive Queue service (VDQM)
  - Tape repack automated media migration
- Users access file by their CASTOR file names

  stagein –M /castor/cern.ch/user/…

CASTOR1 limitations

- Stager catalogue limitations:
  - Stager unresponsive beyond 200k disk resident files
- Tape migration/recall not optimal
  - Migration streams are statically formed and ordering among files cannot be changed depending on the load picture
  - Tape recalls request for same tape are not automatically bundled together
  - Large footprint from waiting requests
- No true request scheduling
  - Throttling, load-balancing
  - Fair-share
- Operational issues
  - No unique request identifiers
  - Problem tracing difficult
- Stager code had reached a state where it had become practically un-maintainable
  - Based on the >10 years old SHIFT stager with a long history of patches, hacks and add-ons for CASTOR1

DM

CASTOR2

CERN IT Department

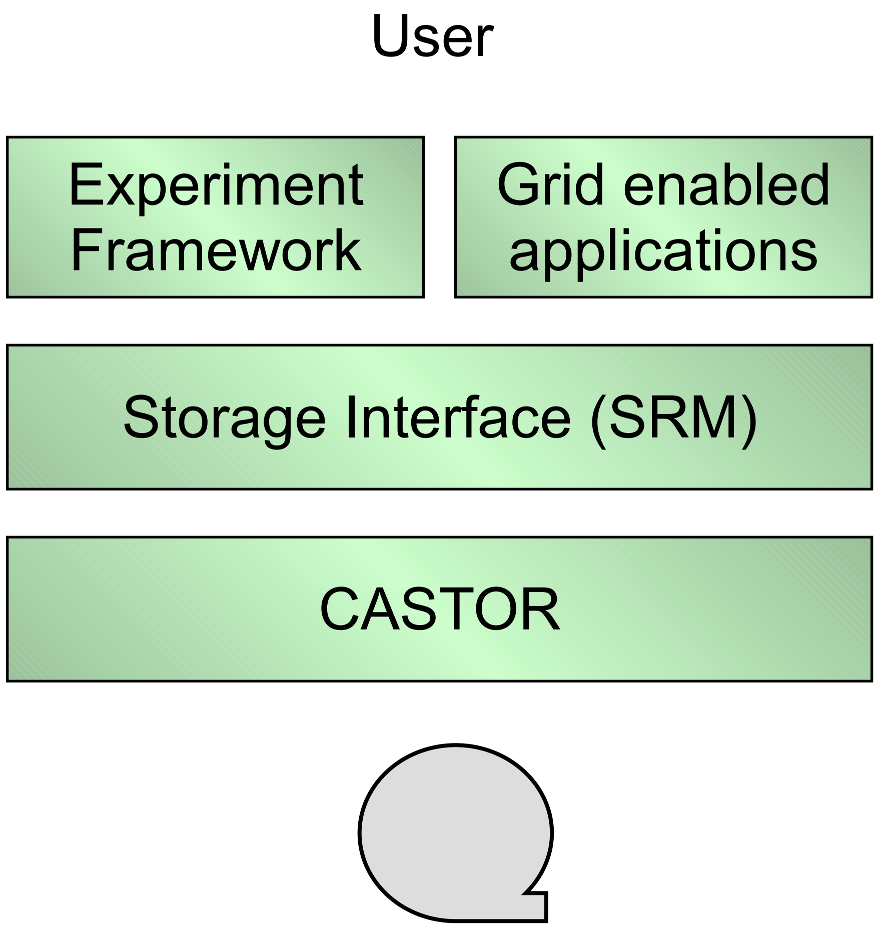
- The original CASTOR plans from 1999 contained a development of a new stager
  - The re-use of the SHIFT stager was temporary
- Project proposed at 2003 CASTOR users' meeting: develop a replacement for the CASTOR1 stager
  - The CASTOR1 stager had already proved to not scale to meet LHC requirements
  - Authors :
    - Originally : Olof Bärring, Ben Couturier, Jean-Damien Durand, Sebastien Ponce
    - Currently : Sebastien Ponce, Giuseppe Lo Presti, Giulia Taurelli, Rosa Garcia Rioja, Dennis Waldron, Steven Murray, Maria Isabel Serrano, Victor Kotlyar, ...

CASTOR2 Proposal

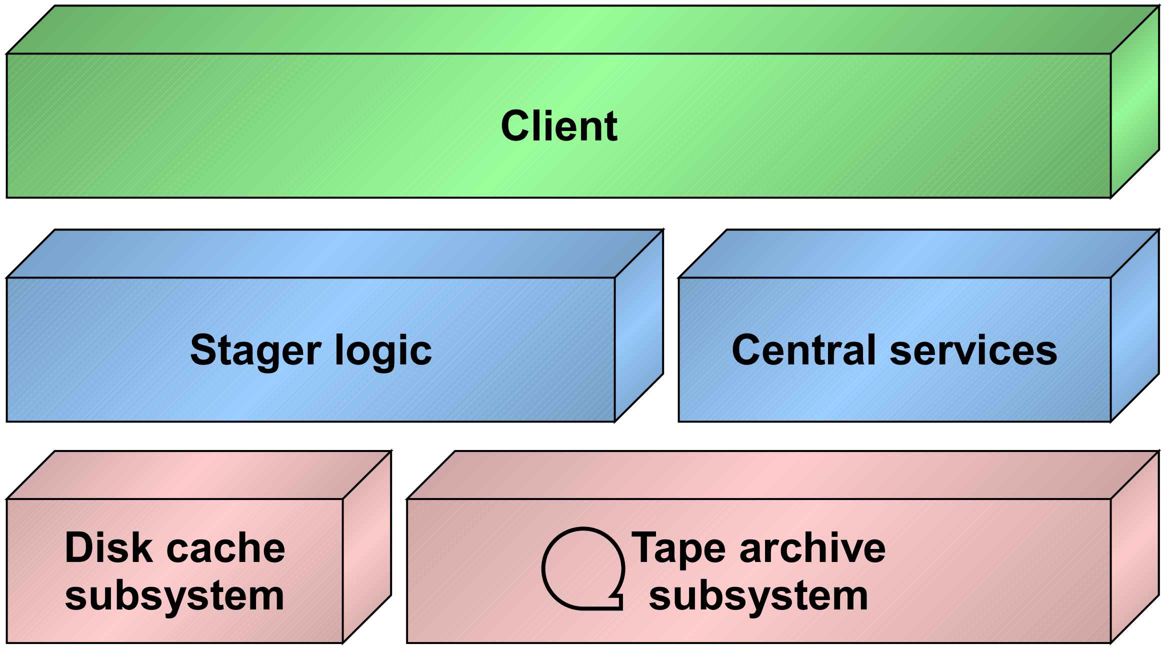
- Pluggable framework rather than total solution
  - True request scheduling
    - delegate the scheduling to a pluggable scheduler, possibly using third party sofware
  - Policy attributes
    - externalize policy engines governing the resource matchmaking
- Restricted access to storage resources to achieve predictable load
  - No random rfiod eating up the resources behind the back of the scheduling system
- Disk server autonomy as far as possible
  - In charge of local resources: file system selection and execution of garbage collection
  - Loosing a server should not affect the rest of the system

Outline

Context View



General Picture

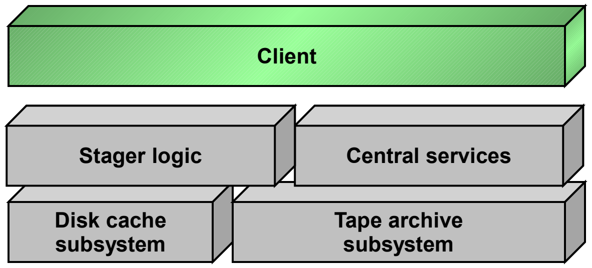


General Picture

- Key requirements
  - Fault tolerance
  - Scalability
  - Transaction-like behavior
- Design features
  - Distributed system
  - Stateless replicated daemons
  - Database-centric architecture
    - State information stored in a RDBMS
    - Rely on the DBMS performances in terms of fault tolerance

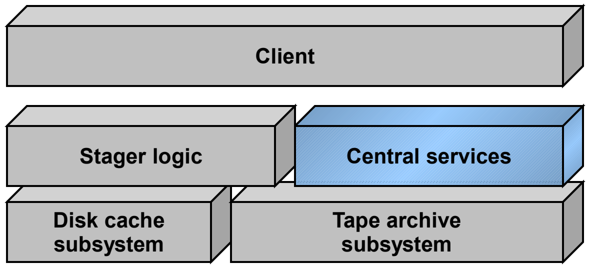
Client deliverables

- Command line interface
  - stager commands (**`stager_xxx`**)
  - RFIO commands (**`rfxxx`**)
- Client API
  - only C
  - internal API in C++
- Supported Protocols
  - RFIO: rfio://server:port//castor/cern.ch/...
  - ROOT: root://server:port//castor/cern.ch/...
  - XROOT: rootd://server:port//castor/cern.ch/...
  - GridFTP:
    - internal (via SRM) : gsiftp://server:port//castor/cern.ch/...
    - external : gsiftp://server:port//local/mnt/point/...
- SRM v1 and v2 interfaces

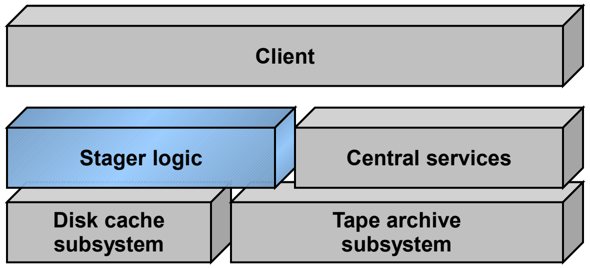


Central Services

- NameServer
  - Database for the Castor "FileSystem"
  - Stores tape-related info as well
- Volume and Drive Queue Manager (VDQM)
  - Daemon for tape queue management
- Volume Manager (VMGR)
  - Archive of all tapes available in the libraries
- Castor User Privileges (CUPV)
  - Authorization daemon: provides rights to users and admins for tape related operations



Stager Logic



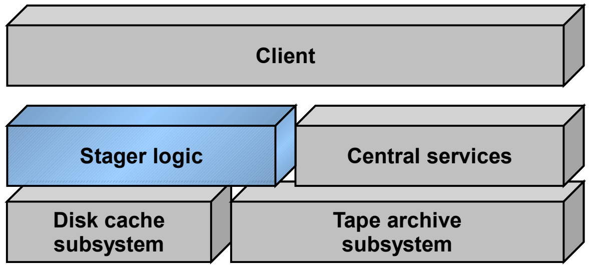
- Design principles
  - Decisions taken:
    - at DB level (stored procedures), or
    - by external plugins (scheduler, policies)
  - Typical decisions
    - Preparation of ***migration*** or ***recall*** streams
    - Weighting of file systems used for migration/recall
    - Garbage collection decisions
  - Actions performed by dedicated daemons

DM

Stager Architecture

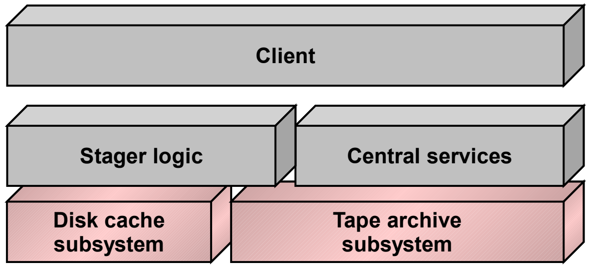
CERN IT Department

- Database centric architecture
  - daemons are stateless
  - Well defined database interfaces separated from the rest of the code
  - only **Oracle** is fully supported
- Stateless components
  - can be restarted/parallelized easily
    ⇒no single point of failure
  - Stager split in many independent services
    - distinction between queries, user requests and admin requests
    - fully scalable
- Minimal footprint of inactive requests
  - Requests are not instantiated in terms of processes until they run
    - Stored in DB and/or scheduler while waiting for resources
    - Number of *migrator / recaller* instances ~ nb drives (no process instances while waiting for drive)



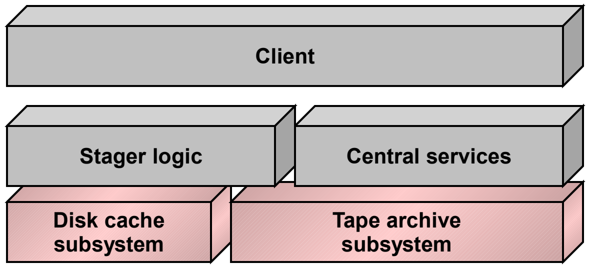
Disk Cache and Tape Archive

- Mainly scheduled disk access
  - All user requests are scheduled
  - Advanced scheduling features for ‘free’ (e.g. fair-share)
  - Only **LSF** is supported
    - **Maui** used to be but development froze last year
- For analysis, unscheduled disk access
  - XROOT does the scheduling on the fly
    - And throttling in case of concurrent streaming accesses
- Dynamic *migration / recall* streams to / from tape
  - Multiple concurrent requests for same volume will be processed together
  - New requests arriving after the stream has started are automatically added to the stream



Disk Cache and Tape Archive

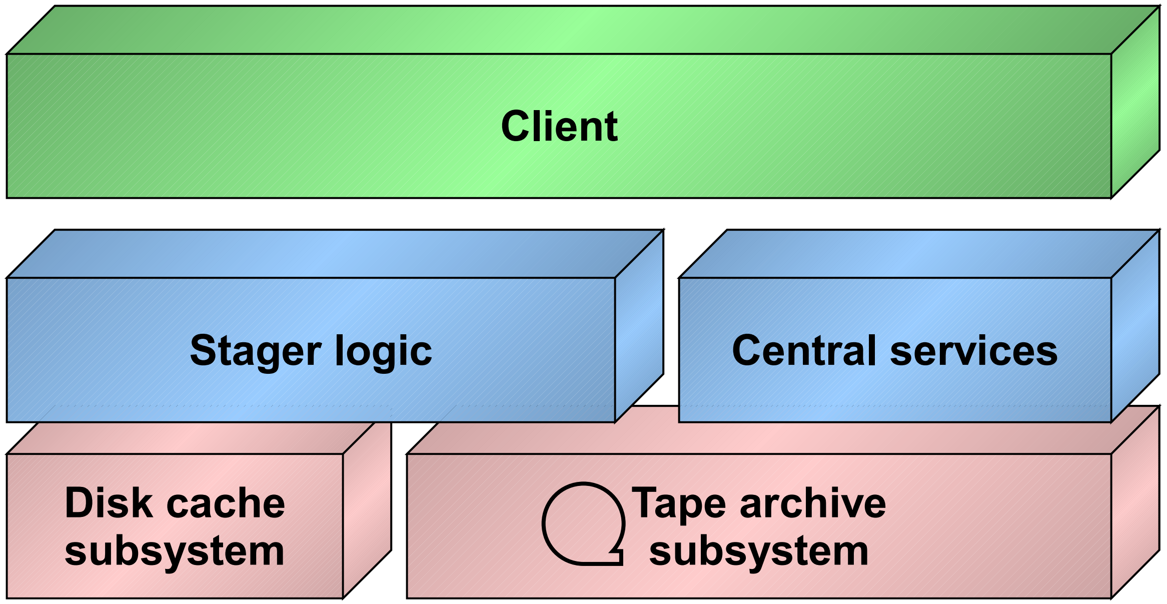
- Pluggable policies
  - For recall, migration, I/O scheduling, GC
  - Defined per disk pool but centrally written
  - Allows support for
    - volatile storage (GC, no migration)
    - durable storage (no GC, no migration)
    - permanent storage (GC, migration)
- "Pluggable" protocols
  - RFIO and ROOT internal, XROOT, GridFTP both internal and external
  - "Easy" addition of new protocols
    - Via plugin mechanism
    - Typically no more than 200 lines of C^{++}



Security and safety aspects

- Authorization
  - per file ACLs at the namespace level
  - restricted access to diskservers (rootd, rfio, xrootd)
- Authentication
  - strong authentication under work
    - available in 2.1.8 but not yet at production level
- Resiliency against hardware failures
  - any node can die with no major impact
    - relying on the DB for data, all deamons can be replicated
- Disaster recovery
  - regular backups of the DBs

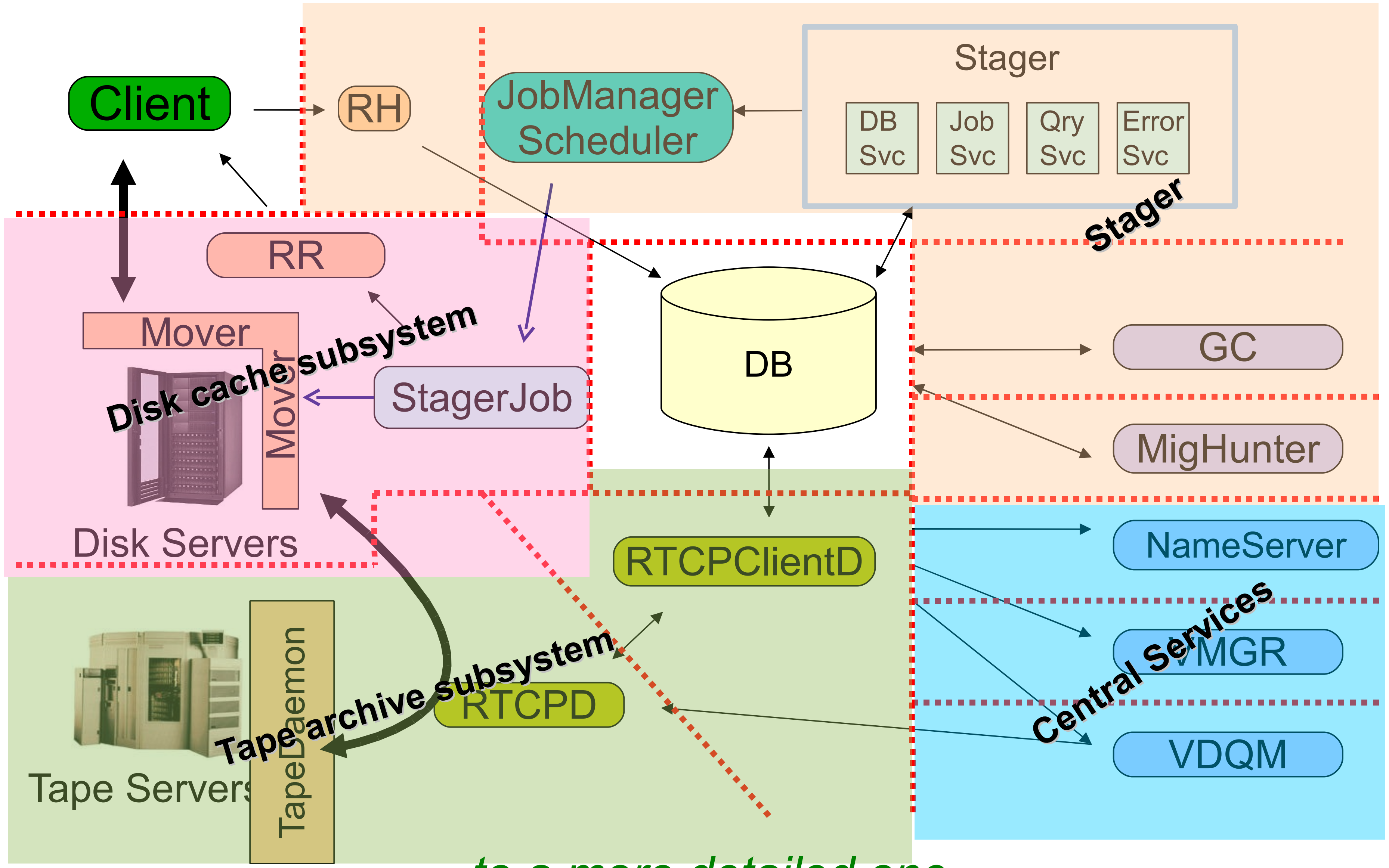
Castor 2 Architecture



From the "simple" view …

Castor 2 Architecture

CERN IT Department



to a more detailed one

Old and new components

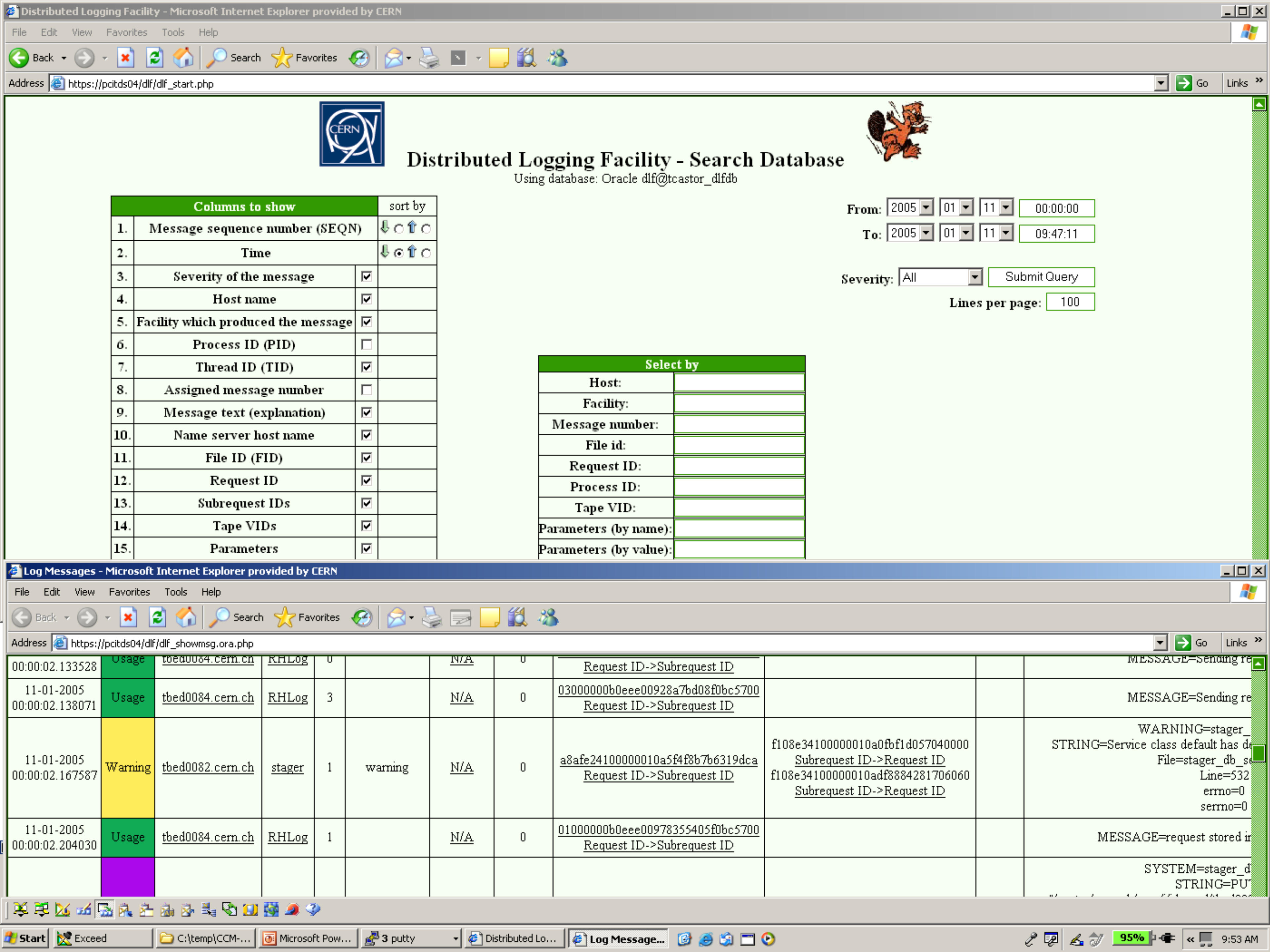
- Castor 2 has its roots in mid 1990s
  - Several components have been left almost unchanged
    - E.g. the Central Services
  - New components have been written from scratch
  - Happy mix of old and new code
    - Different styles due to different developers and (mostly) different languages
    - Most C++ code is interfaced in C

…not a surprise taking into account time extension of the project and number of involved people!

Extra components

CERN IT Department

- Monitoring daemons
  - rmNodeDaemon runs on all diskservers
  - rmMasterDaemon collects the information
- JobManager
  - a wrapper around the LSF API
    - LSF API is non thread safe
- LSF Plugin
  - Select best candidate resource (file system) among the set proposed by LSF
- Distributed logging facility (DLF)
  - a central DB allowing easy log browsing



Distributed Logging Facility - Microsoft Internet Explorer provided by CERN

Address https://pcitds04/dlf/dlf_start.php

Distributed Logging Facility - Search Database

Using database: Oracle dlf@tcastor_dlfdb

Columns to show			sort by
1.	Message sequence number (SEQN)		⇓ ○ ⇑ ○
2.	Time		⇓ ● ⇑ ○
3.	Severity of the message	☑	
4.	Host name	☑	
5.	Facility which produced the message	☑	
6.	Process ID (PID)	☐	
7.	Thread ID (TID)	☑	
8.	Assigned message number	☐	
9.	Message text (explanation)	☑	
10.	Name server host name	☑	
11.	File ID (FID)	☑	
12.	Request ID	☑	
13.	Subrequest IDs	☑	
14.	Tape VIDs	☑	
15.	Parameters	☑	

From: 2005 01 11 00:00:00

To: 2005 01 11 09:47:11

Severity: All — Submit Query

Lines per page: 100

Select by	
Host:	
Facility:	
Message number:	
File id:	
Request ID:	
Process ID:	
Tape VID:	
Parameters (by name):	
Parameters (by value):	

Log Messages - Microsoft Internet Explorer provided by CERN

Address https://pcitds04/dlf/dlf_showmsg.ora.php

00:00:02.133528	Usage	tbed0084.cern.ch	RHLog	0		N/A	0	Request ID->Subrequest ID			MESSAGE=Sending re
11-01-2005 00:00:02.138071	Usage	tbed0084.cern.ch	RHLog	3		N/A	0	03000000b0eee00928a7bd08f0bc5700 Request ID->Subrequest ID			MESSAGE=Sending re
11-01-2005 00:00:02.167587	Warning	tbed0082.cern.ch	stager	1	warning	N/A	0	a8afe24100000010a5f4f8b7b6319dca Request ID->Subrequest ID	f108e34100000010a0fbf1d057040000 Subrequest ID->Request ID f108e34100000010adf8884281706060 Subrequest ID->Request ID		WARNING=stager_ STRING=Service class default has de File=stager_db_se Line=532 errno=0 serrno=0
11-01-2005 00:00:02.204030	Usage	tbed0084.cern.ch	RHLog	1		N/A	0	01000000b0eee00978355405f0bc5700 Request ID->Subrequest ID			MESSAGE=request stored in
											SYSTEM=stager_d STRING=PUT

DM

Extra components (2)

CERN IT Department

- Garbage collection
  - gcDaemon running on every diskServer
  - central SQL code taking garbage collection decisions based on SQL polices
- Python policy service
  - allows easy execution of python policies
  - still quite efficient thanks to on the fly precompilation
  - used for recall, stream, migration, scheduling policies, ...

Outline

- CASTOR2 context
  - Scope and constraints
  - History
    - SHIFT, CASTOR 1
  - Requirements
- CASTOR 2 architecture overview
  - blocks and components
  - and their status
- Technology choices
  - about languages
  - UML and the code generation
  - DB centric

About languages

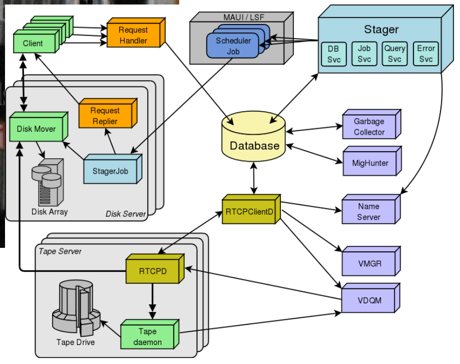
- Object Orientation
  - Java like inheritance
    - Simple, multiple only for interfaces
  - Heavy use of (pure) abstract interfaces
    - Each service/component has one
    - Some services even have several implementations
      - IGCSvc → RemoteGCSvc and OraGCSvc
- Implementation language is C++
  - Still some subparts in C
  - Happy mix, special thanks to code generation
- Castor 1 is pure C, no OO

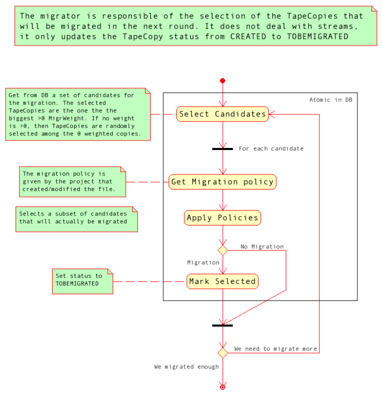
Still around languages

- Admin scripts are in python
  - Still some old ones in perl, should disappear
- No imposed dev environment
  - Wide range of tools among developpers
    - vi(m), (x)emacs
    - jedit, kdeveloper
    - nedit
  - Even different linux distributions
- Documentation
  - Recent documents are tex
  - Older are more word

Architecture design

- Based on UML
  - Component views for the rough architecture
  - Activity diagrams per component
  - State diagrams per object
  - Sequence diagrams per use case
  - Class diagrams for implementation details, per compenent
- Using umbrello
  - Essentially because of its code generation





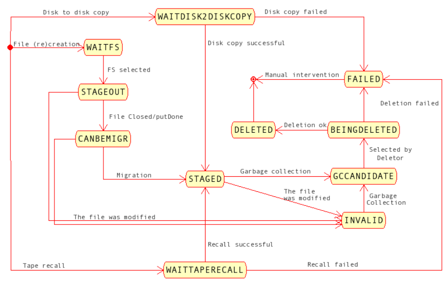
The migrator is responsible of the selection of the TapeCopies that will be migrated in the next round. It does not deal with streams, it only updates the TapeCopy status from CREATED to TOBEMIGRATED

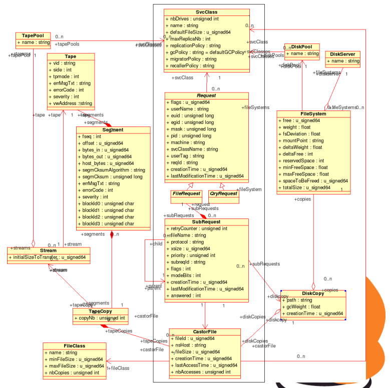
Get from DB a set of candidates for the migration. The selected TapeCopies are the one the the biggest >0 MigrWeight. If no weight is >0, then TapeCopies are randomly selected among the 0 weighted copies.

The migration policy is given by the project that created/modified the file.

Selects a subset of candidates that will actually be migrated

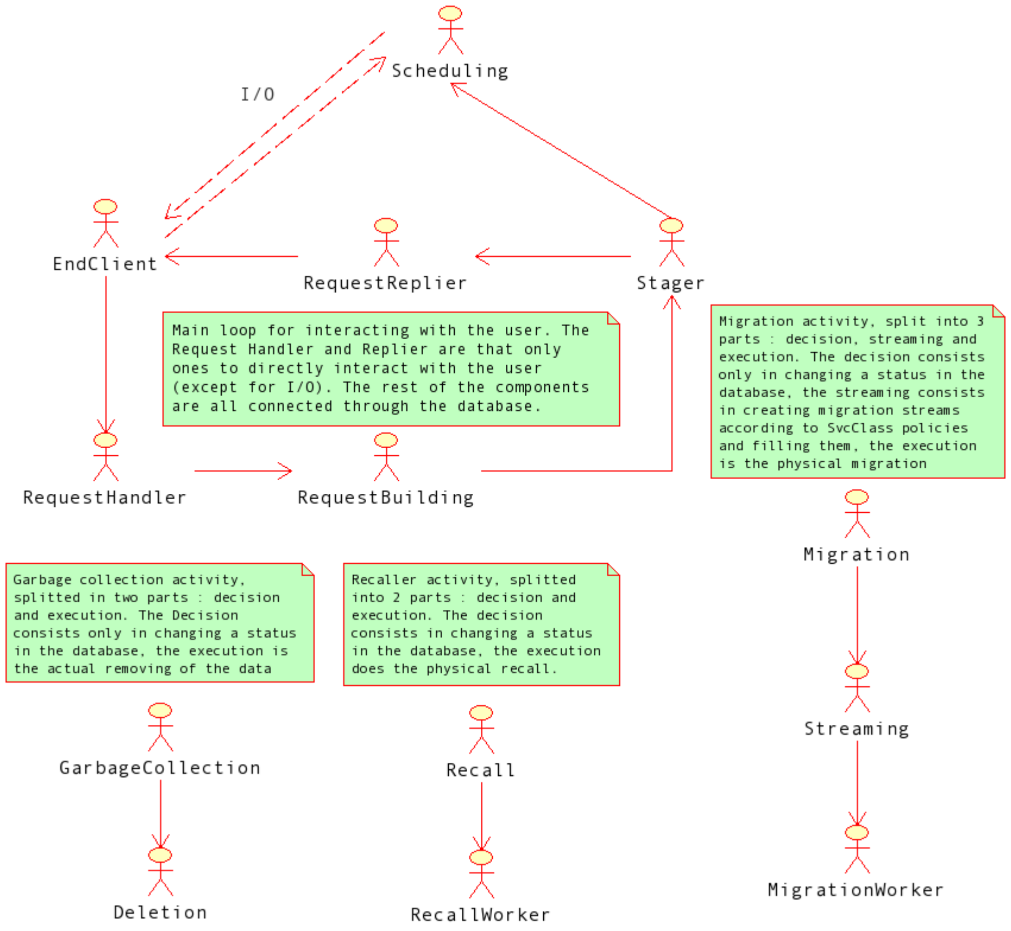
Set status to TOBEMIGRATED





Component views

- Used for designing the overall architecture and the relations between components
- The building block is a component
- The relations mean that the 2 components communicate at some stage



Main loop for interacting with the user. The Request Handler and Replier are that only ones to directly interact with the user (except for I/O). The rest of the components are all connected through the database.

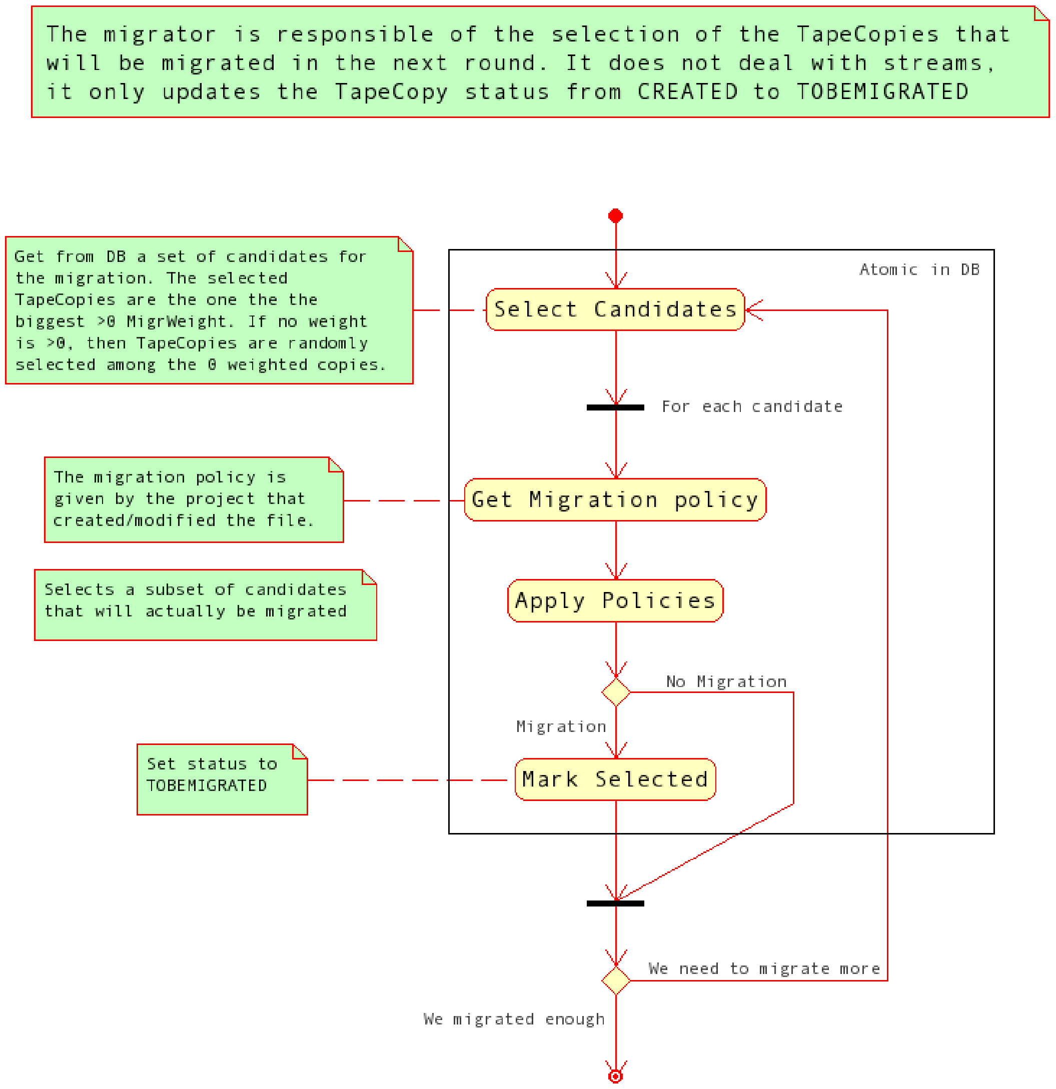
Migration activity, split into 3 parts : decision, streaming and execution. The decision consists only in changing a status in the database, the streaming consists in creating migration streams according to SvcClass policies and filling them, the execution is the physical migration

Garbage collection activity, splitted in two parts : decision and execution. The Decision consists only in changing a status in the database, the execution is the actual removing of the data

Recaller activity, splitted into 2 parts : decision and execution. The decision consists in changing a status in the database, the execution does the physical recall.

Activity diagrams

- Used for describing the work flow of a component
- The building bloc is a simple (atomic) operation
- Arrows indicate the flow of time



The migrator is responsible of the selection of the TapeCopies that will be migrated in the next round. It does not deal with streams, it only updates the TapeCopy status from CREATED to TOBEMIGRATED

Get from DB a set of candidates for the migration. The selected TapeCopies are the one the the biggest >0 MigrWeight. If no weight is >0, then TapeCopies are randomly selected among the 0 weighted copies.

The migration policy is given by the project that created/modified the file.

Selects a subset of candidates that will actually be migrated

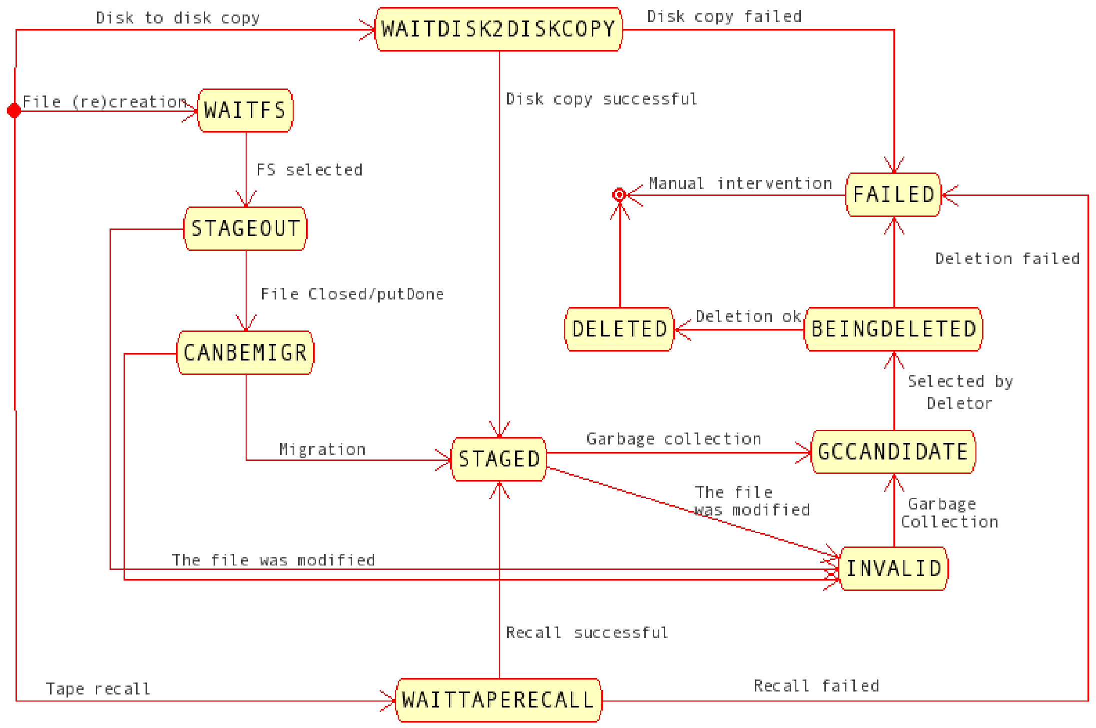
Set status to TOBEMIGRATED

DM

State Diagrams

CERN IT Department

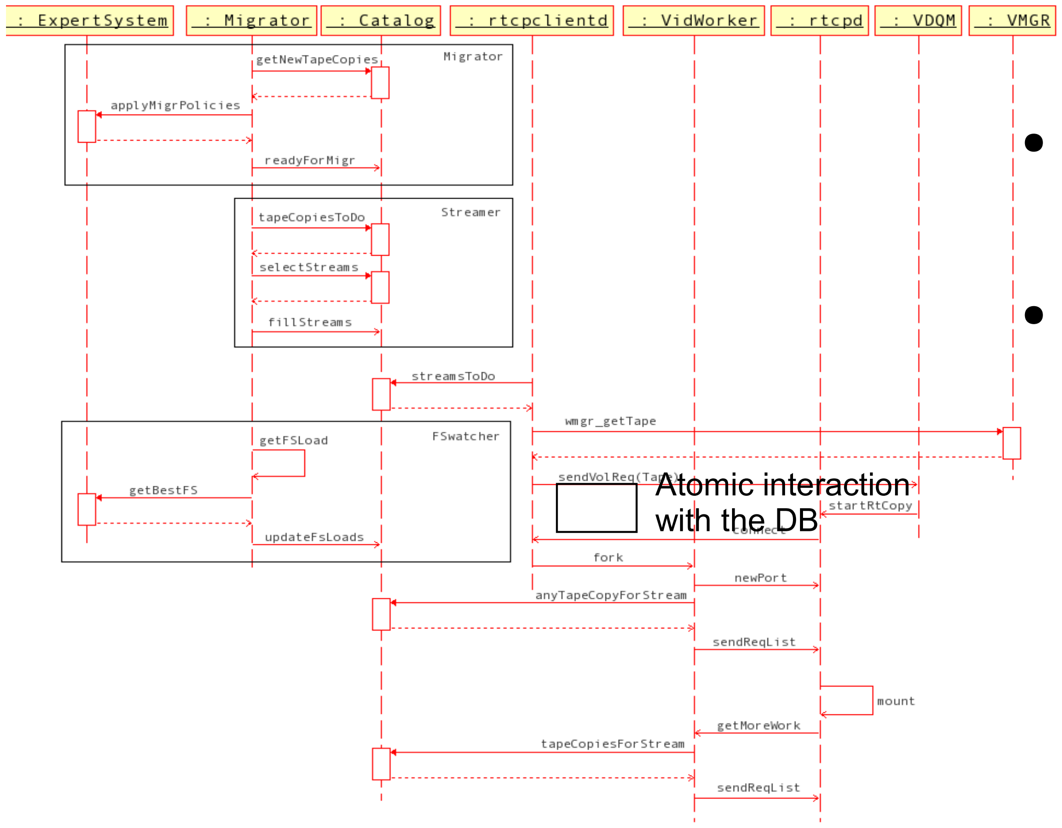
- Used for describing the possible states and state transitions of objects
- Allows to easily find out implications of adding a new state or state transition
- Building block is a state
- Arrows indicate state transitions



CERN IT Department

Sequence diagrams

- Used for analyzing interactions between components and their timing
- Useful to avoid deadlocks and inefficiencies due to bad granularity



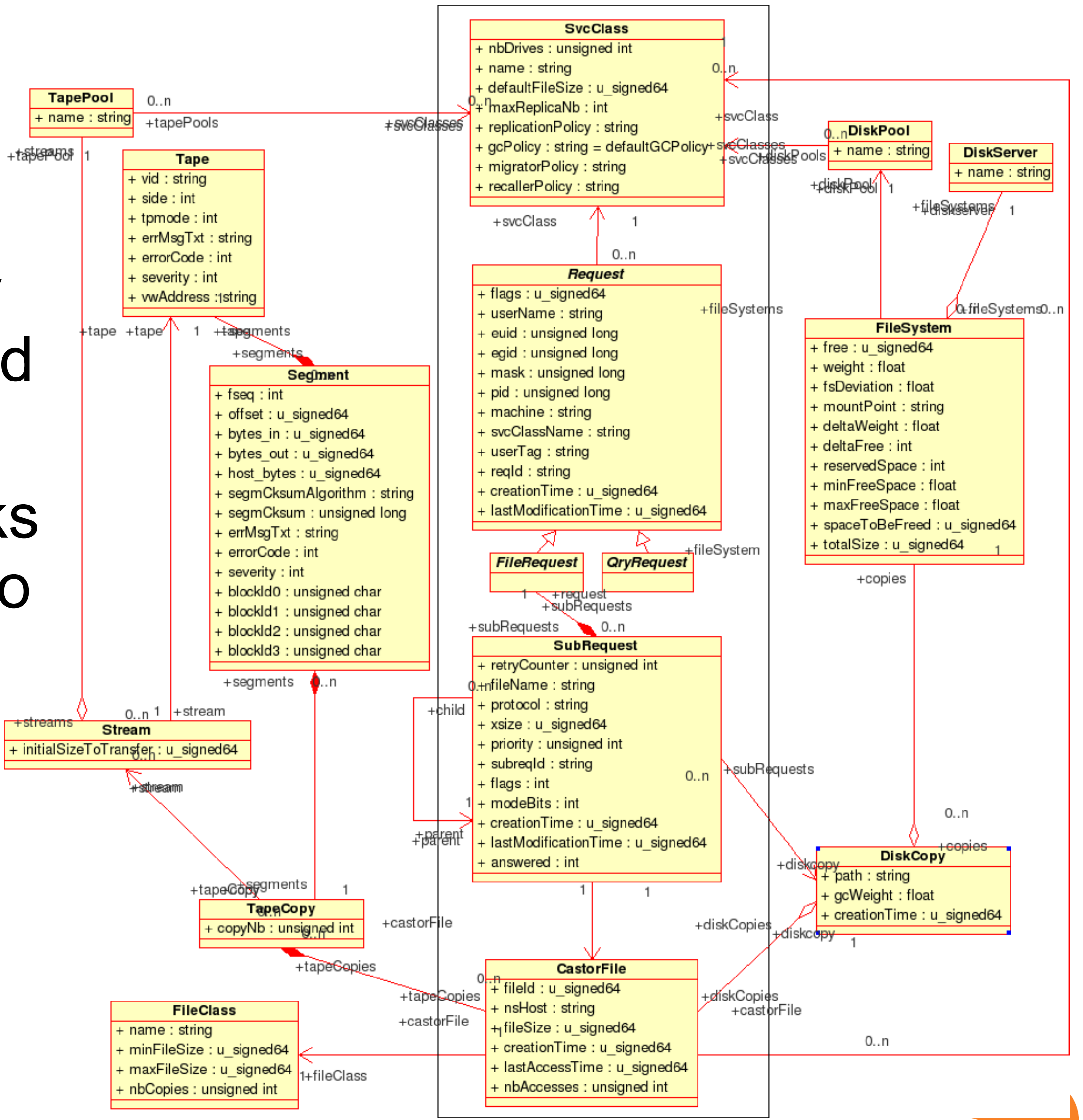
- Blocks are actions
- Arrows mean communication between components

DM

Class diagrams

CERN IT Department

- Used of fine grained design.
- Blocks are the items handled by the code (mapped to classes)
- Relations are links from one object to another
- This is the input of the code generation



Usage of UML diagrams

- For the design
  - At the project level
  - At the code level
  - For the database schema
    - class diagram maps to the DB schema
- For code generation
  - Of header files and object implementation (data objects)
  - Of DB scripts : schema creation/deletion
  - Of a DB access layer in the code
    - allows to store/retrieve/update/(un)link objects
  - Of I/O libraries dealing with objects

Goal of code generation

- Saves typing for class declaration and implementation
- Automates some facilities (object printing, introspection)
- Automates streaming and DB access
- Generates C interface to C++ code
- Allows easy maintenance

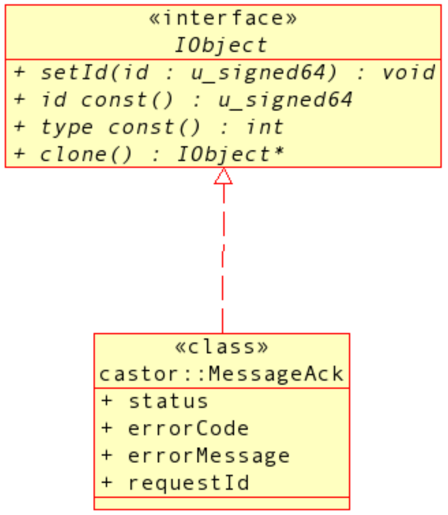
```
castor::IObject* obj = sock->readObject()
…
castor::BaseAddress ad;
ad.setCnvSvcName("DbCnvSvc");
…
svcs()->createRep(&ad, obj);
```

Core of the Request Handler code

Class implementation

CERN IT Department

C++ code



.hpp

```
class MessageAck : public virtual IObject {
…
private:
    /// Status of the request
    bool m_status;
    /// Code of the error if status shows one
    int m_errorCode;
```

.cpp

```
void castor::MessageAck::print(…) const {
  …
  stream << indent << "status : "
         << m_status << std::endl;
  stream << indent << "errorCode : "
         << m_errorCode << std::endl;
```

.h

```
int C_MessageAck_create(struct C_MessageAck_t**);
int C_MessageAck_print(struct C_MessageAck_t*);
```

And C interface

CInt.cpp

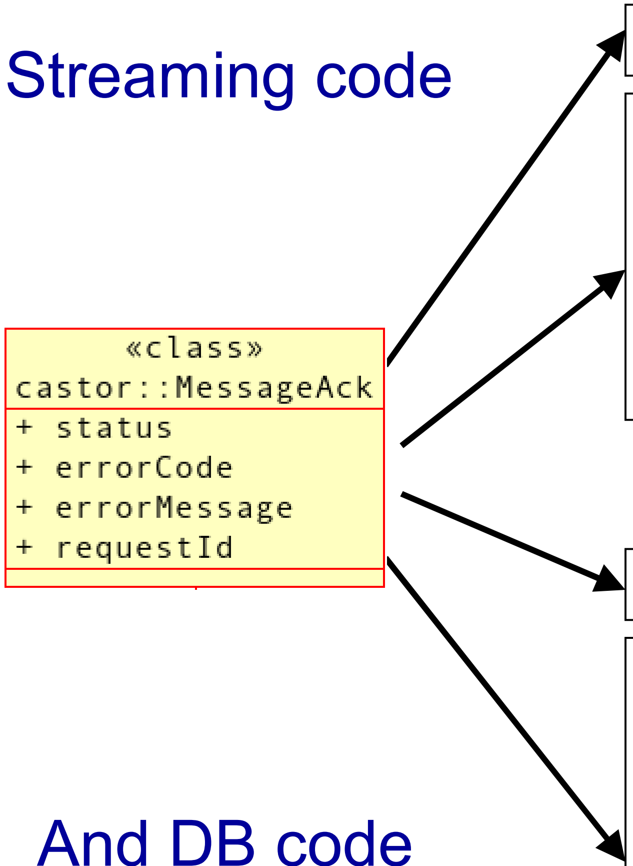
```
int C_MessageAck_create(castor::MessageAck** obj) {
  *obj = new castor::MessageAck();
  return 0;
}
int C_MessageAck_print(castor::MessageAck* instance) {
  instance->print();
  return 0;
}
```

Converters

CERN IT Department

Streaming code

And DB code



Stream*Cnv.h/cpp

```
virtual void createRep(IAddress*, IObject*);
```

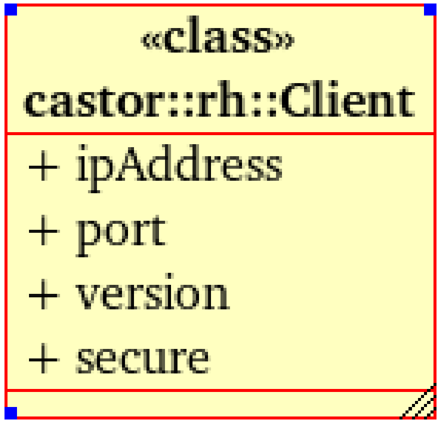
```
void … StreamMessageAckCnv::createRep(…) {
  …
  ad->stream() << obj->type();
  ad->stream() << obj->ipAddress();
  ad->stream() << obj->port();
  ad->stream() << obj->id();
```

Ora*Cnv.h/cpp

```
virtual void createRep(IAddress*, IObject*);
```

```
void … StreamMessageAckCnv::createRep(…) {
  …
  const std::string insertStmStr =
"INSERT INTO Client (ipAddress, port, id)…";
  …
 insertStmt = createStatement(insertStmStr);
  …
 insertStm->executeUpdate();
```

DB scripts



castor_oracle_create.sql

```
/* SQL statements for type Client */
CREATE TABLE Client (ipAddress NUMBER, port NUMBER, id
INTEGER PRIMARY KEY) INITRANS 50 PCTFREE 50;
```

castor_oracle_drop.sql

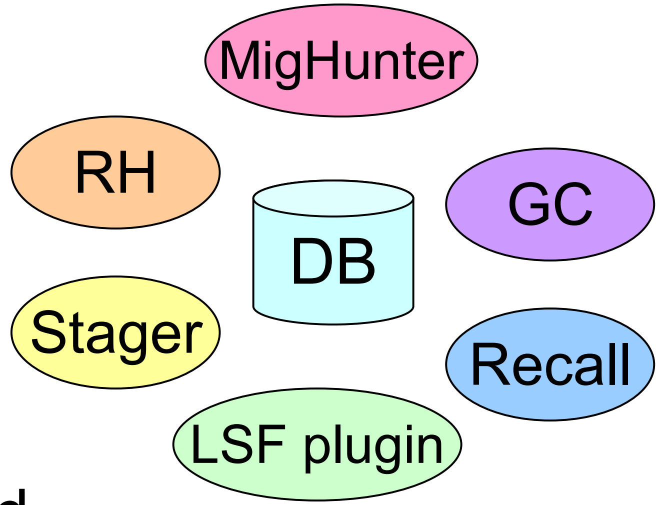
```
/* SQL statements for type Client */
DROP TABLE Client;
```

DM

Database Centric soft

CERN IT Department

- Reliability
  - No single point of failure
    - replication of components
  - Locking handled by the DB
  - Backups handled by the DB
- Scalability
  - All component can be replicated
  - No catalog in memory
  - Limited by DB scalability
    - No risk from the space point of view
    - CPU is the limit. A lot of tuning done.
    - No fear so far, CPU usage in a production instance running stress testing is ~10%



That's it for now