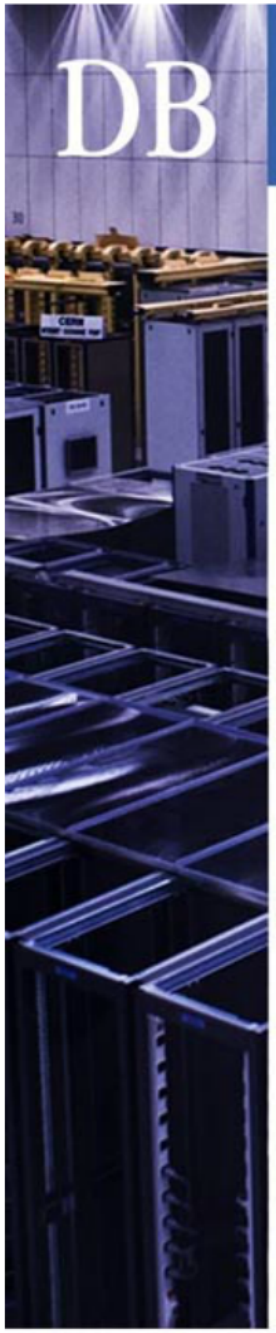


DB Database Services

CERN IT Department

Going deeper into Real Application Testing

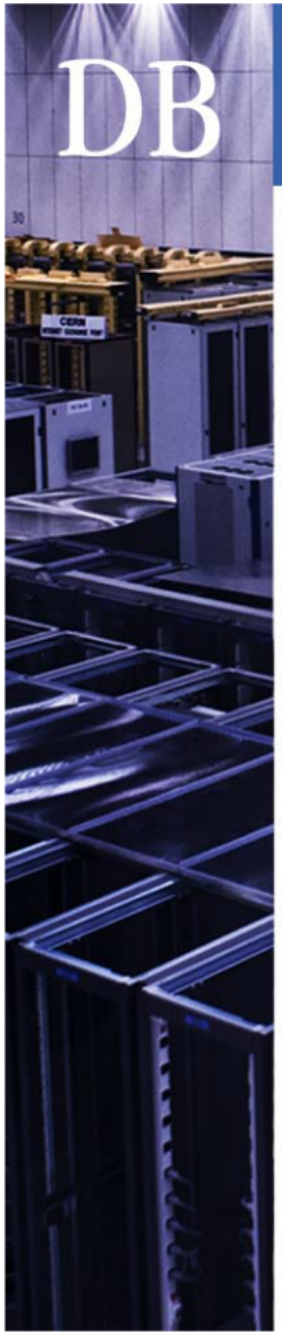
Learn how to make smoother migrations to 11g

Mariusz Piorkowski
Eric Grancher
Katarzyna Dziedziniewicz-Wojcik
CERN IT-DB

CERN IT Department
CH-1211 Geneva 23
Switzerland
www.cern.ch/it

Database SERVICES

CERN



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- Why Real Application Testing?
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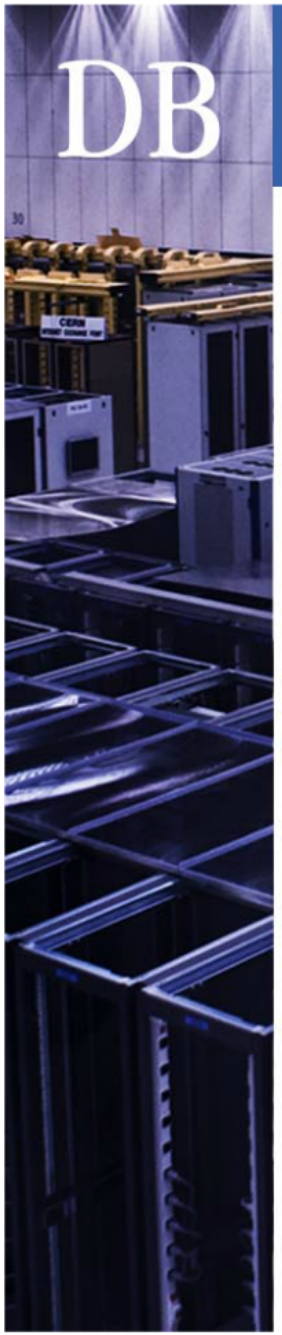
  - measure the difference,
  - ... and performance issue,
- Methodology
- Recommendations and conclusions



CERN

CERN IT Department

- The largest particle physics lab in the world

Annual budget

982 mln CHF

687 mln GBP

+ External funding for experiments

People:

- 2400 staff
- 900 students (post-doc and undergradute)
- 9000 users
- 2000 contractors

Eight Observer States

European Commission, USA, Russian Federation, India, Israel, Japan, Turkey, UNESCO

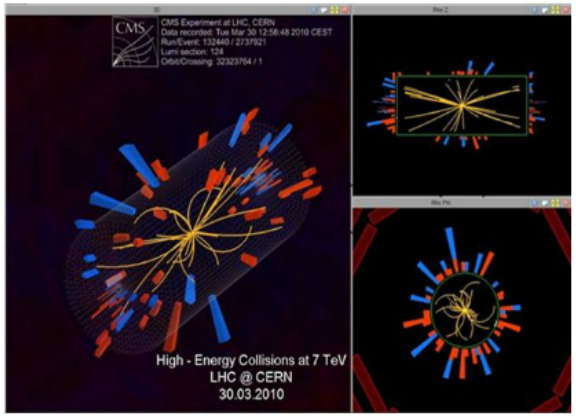
The largest particle accelerator & detectors

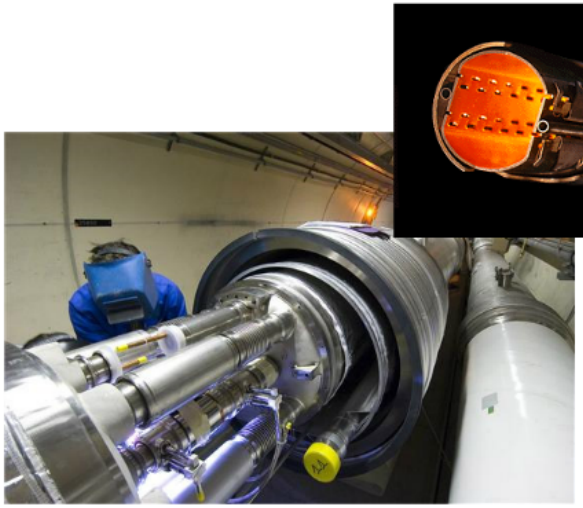
- 17 miles (27km) long tunnel
- thousands of superconducting magnets
- ultra vacuum 10x emptier than on Moon
- coldest place in the Universe
- 600 million collisions per second detected by hundreds of million sensors

Total cost:

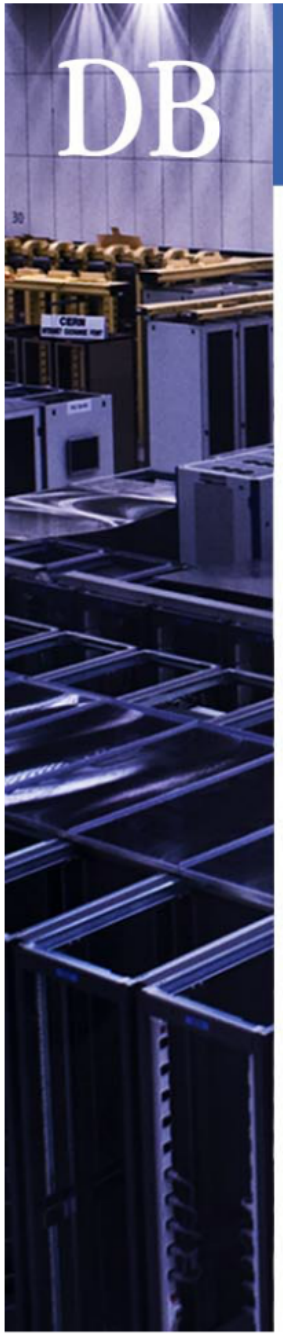
4.6

BCHF





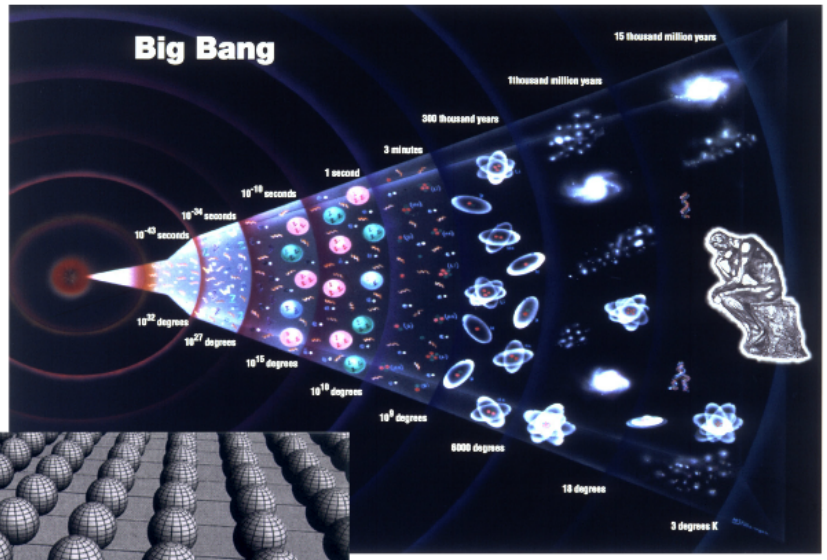
-271°C



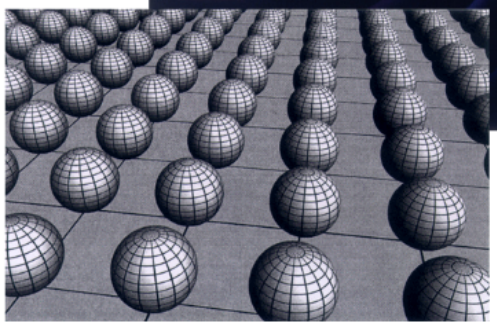
Answering fundamental questions

- What is mass?
- What is 96% of the Universe made of?
- Where did the antimatter go to?
- What was the universe like just after the « Big Bang »?

Higgs Boson

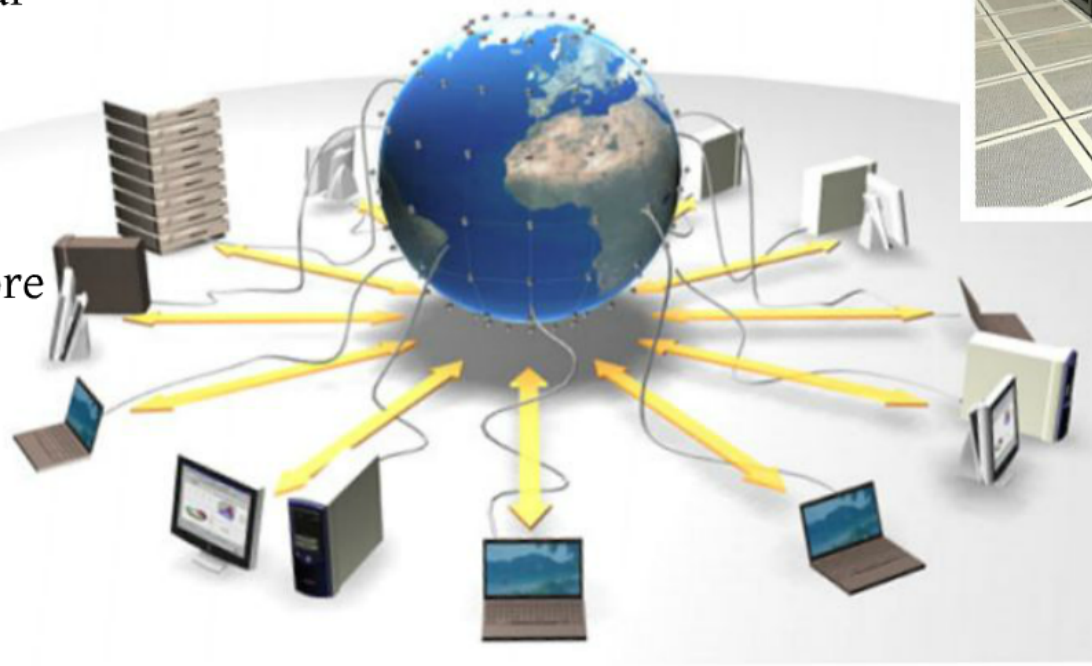


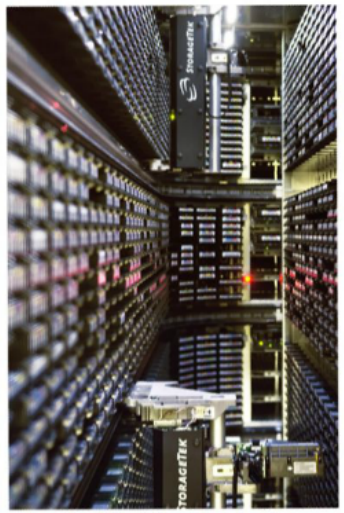
- Are there extra dimensions of space?



Worldwide LHC Computing Grid

- 25 Petabytes (25 millions Gigabytes) of data stored and analysed every year
- > 79,000 physical CPUs
- > 282,000 logical CPUs
- 140 computer centres around the world – more than 8000 physicists





Database SERVICES

At the heart of CERN, LHC and Experiment Operations

CERN IT Department

http://cern.ch/it-dep/db/

IT/DB GROUP

Experiment Offline Databases
9 Production DBs, 7 Integration DBs
5 Tests DBs, 7 Standby DBs

Streams

Streams

Tier-1 Centres

Experiment Online Databases
4 Production DBs

Data

LHC Experiments

LHCb

CMS

ATLAS

ALICE

RAW Data

CASTOR
CERN Advanced STORage manager

21 Production DBs
4 Development DBs

Middleware
73 Application Servers

Administrative/IT/ Engineering Databases
17 Production DBs
11 Development DBs
4 Ref/Test DBs

Accelerators ACC
12 Production DBs

LHC Operations

PARTNERS:

CERN openlab

ORACLE

CERN

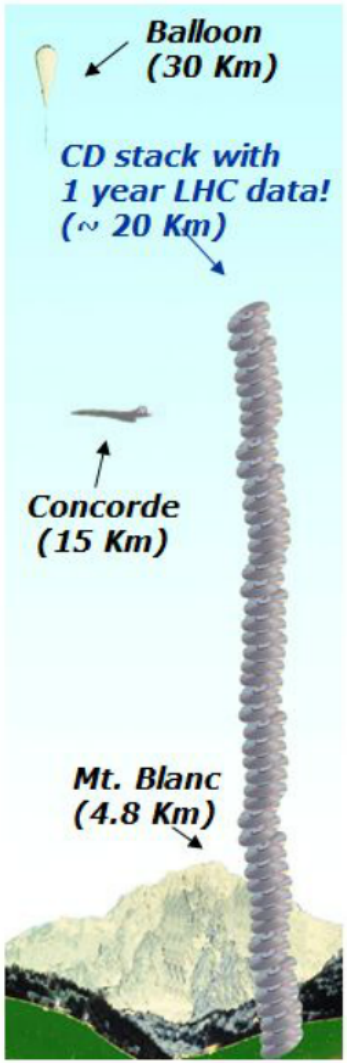
CERN databases in numbers

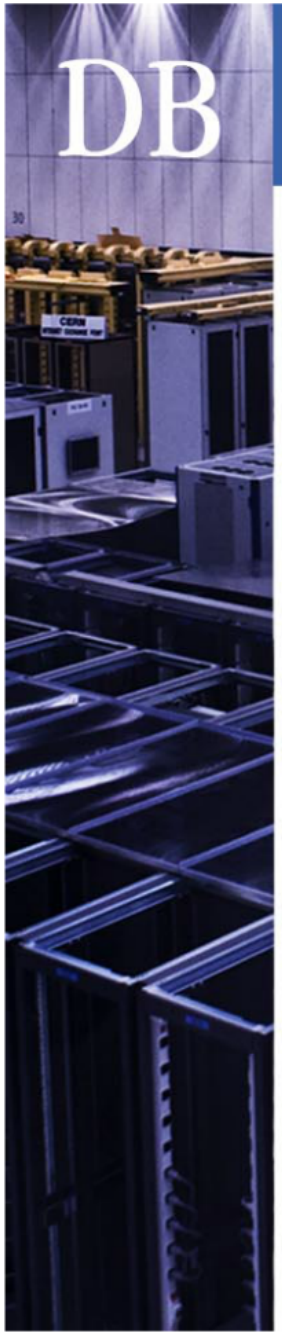
CERN databases services

- ~130 databases, most of them database clusters (Oracle RAC, 2 – 6 nodes)
- Currently over 3000 disk spindles providing more than ~3PB raw disk space (NAS and SAN)
- MySQL service starting

Some notable databases at CERN

- Experiments' databases – 14 production databases
  - Currently between 1 and 12 TB in size
  - Expected growth between 1 and 10 TB / year
- LHC accelerator logging database (ACCLOG) – ~94 TB, >3.5 * 10^{12} rows, expected growth up to 70TB / year
- ... Several more DBs in the 1-2 TB range





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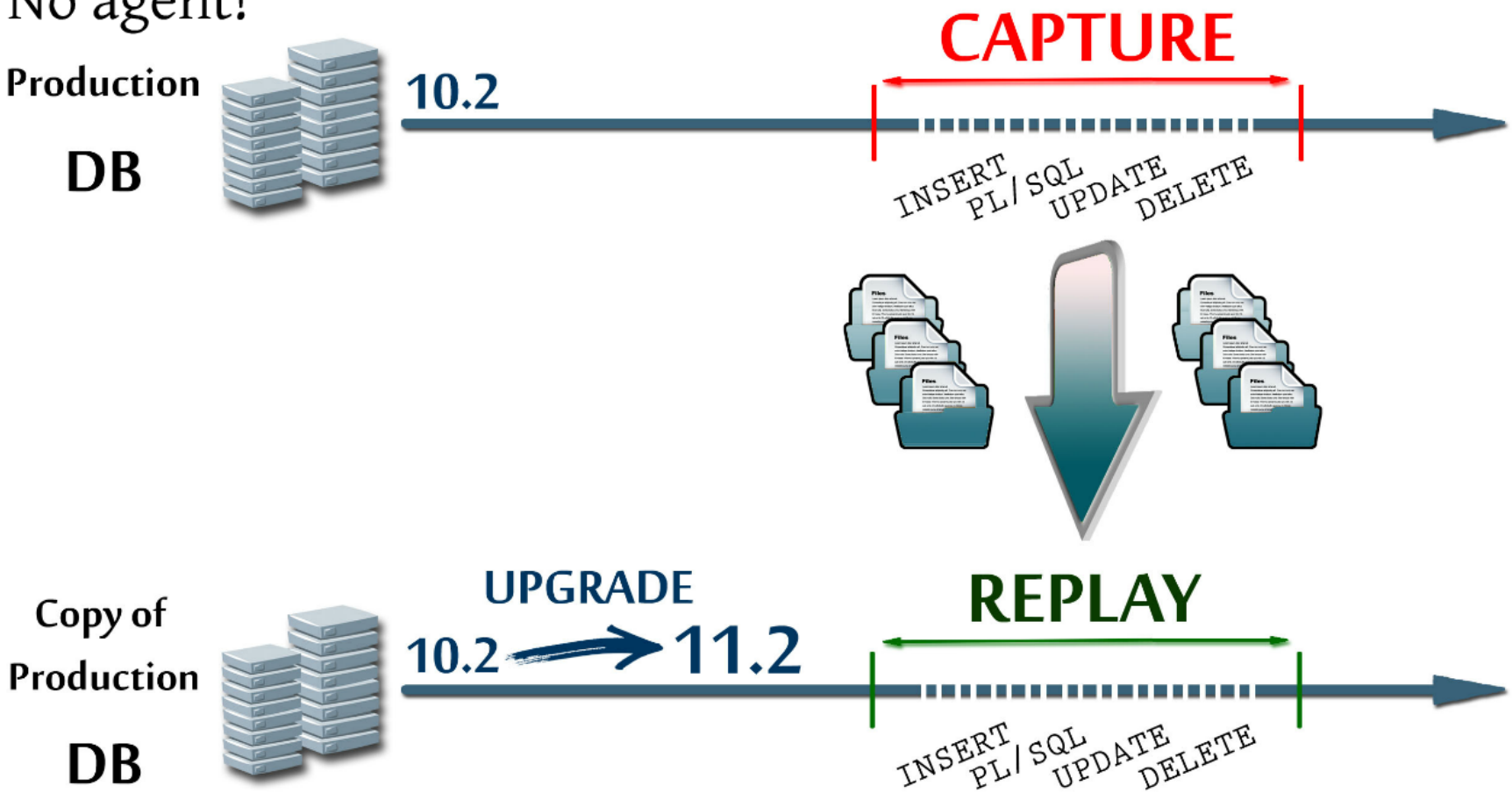
Why Real Application Testing?

- "DBAs and developers test, not the users!"
- All developers and DBAs have been dreaming trying for years: replaying _the_ real workload
- Capture in 9.2+, replay in 11.1+
  - we started with capture 10.2
  - Real Application Testing is licensable option for Oracle Database EE: Database Replay + SQL Performance Analyzer (SPA) + SQL Tuning Sets (STS)

Database replay schematics

- No agent!



Enabled by default, if needed relink:

make -f ins_rdbms.mk rat_on ioracle or chopt enable rat

For the DB whole lifecycle

- major upgrades
- minor upgrades (CPU/PSU, one-off patches)
- platform change (hardware / OS change)
- database parameters change (sga_max_size, compatible, etc.)
- application schema change (new/removed index, etc.)
- execution plan changes (outline/SQL Plan Management...)
- consolidation / adding workload
- compression / partitioning
- and also for validating backup...

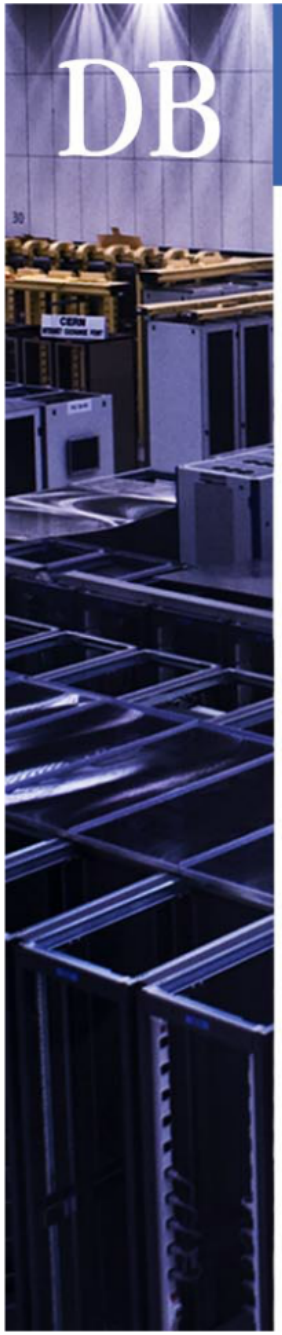
NOT ONLY FOR UPGRADES!

Database Replay

- Fully accessible, either
  - from Enterprise Manager
  - or from command line (PL/SQL packages)
- WRC binary required for the replay
  - In the RDBMS 11g software
  - Also available from Instant Client

*Instant Client Package - WRC: Workload Replay Client used to replay workload for RAT's DB Replay Feature

- **instantclient-tools-linux-x86-64-11.2.0.2.0.zip** (156,431 bytes) (cksum - 1027842478)
- **oracle-instantclient11.2-tools-11.2.0.2.0.x86_64.rpm** (134,661 bytes) (cksum - 534617225)



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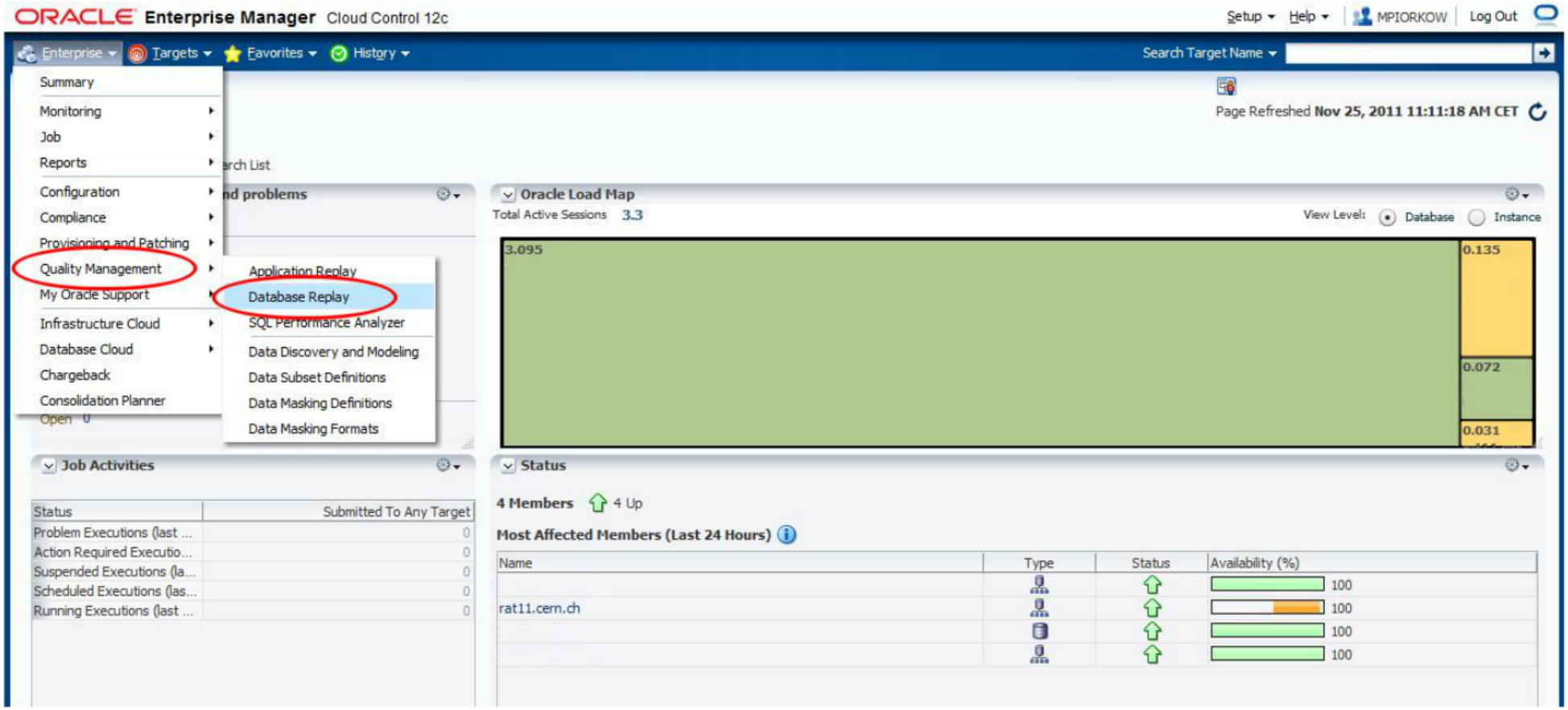
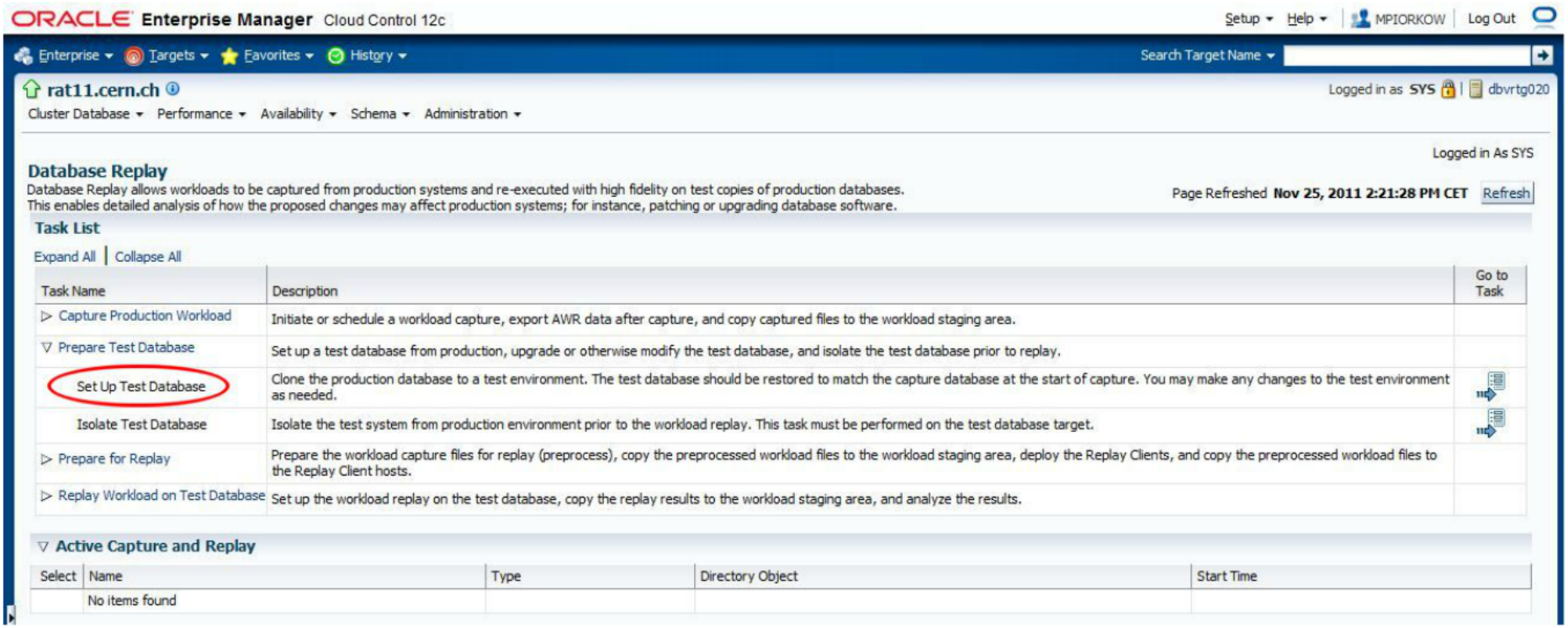
Real Application Testing with EM

- Where to start?

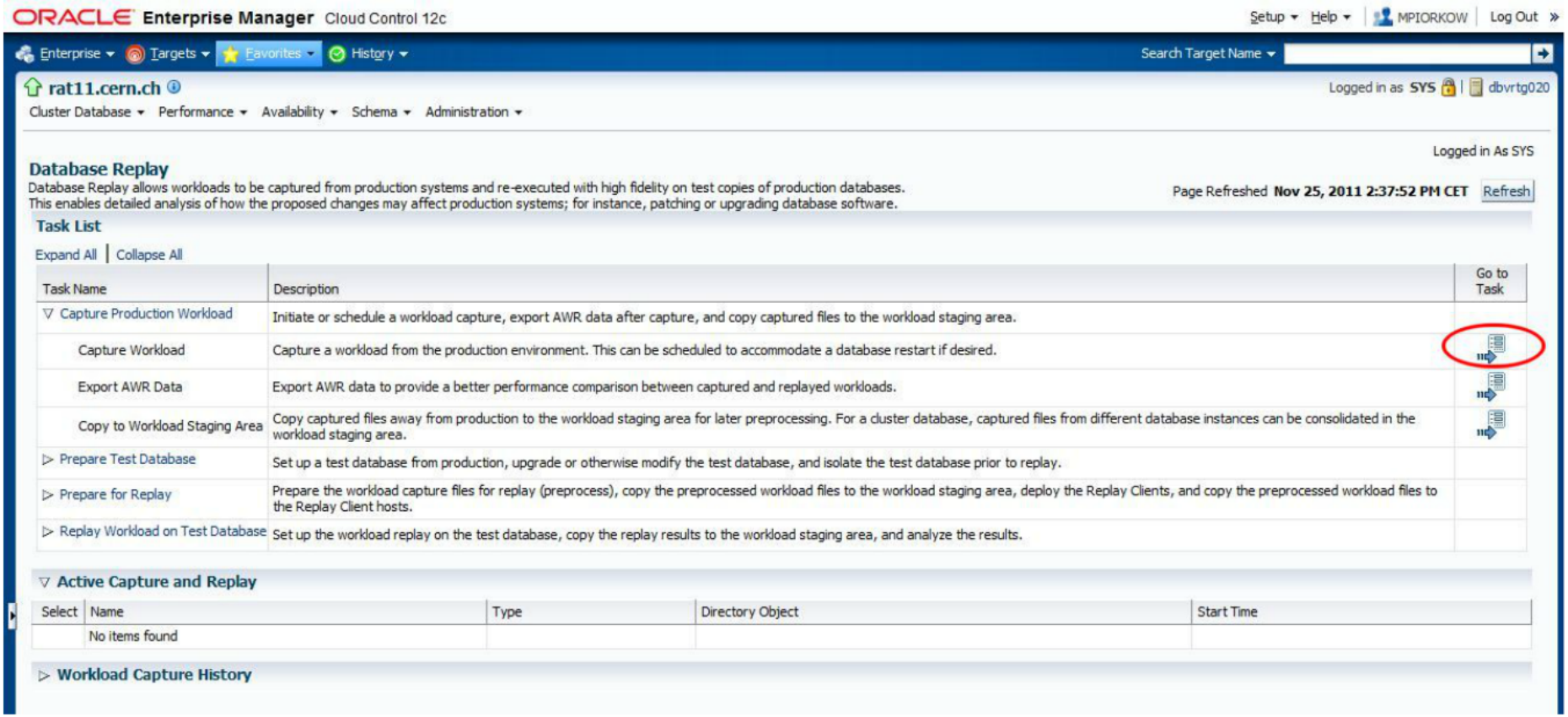


EM - Database Replay

- Possible actions
  - Prepare Test Database

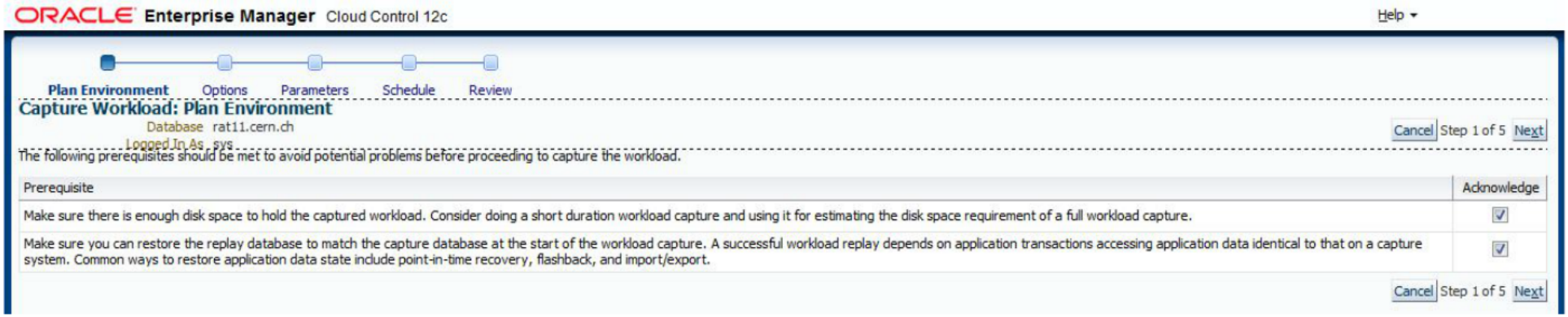


Capturing Workload



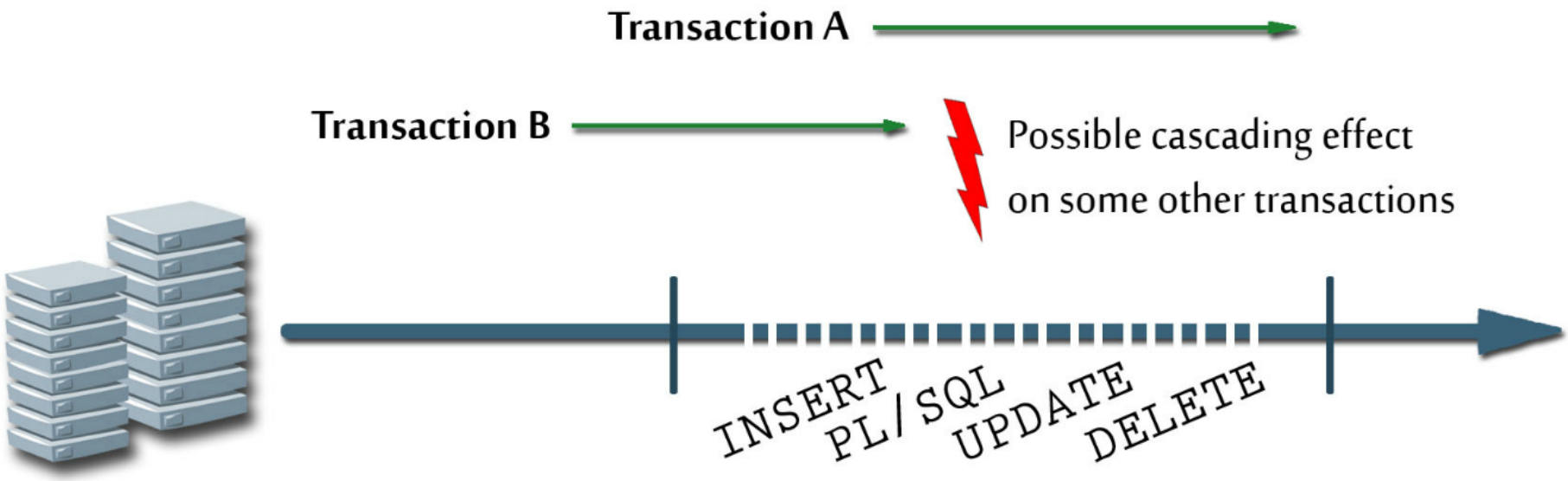
Capturing Workload

- Checking prerequisites



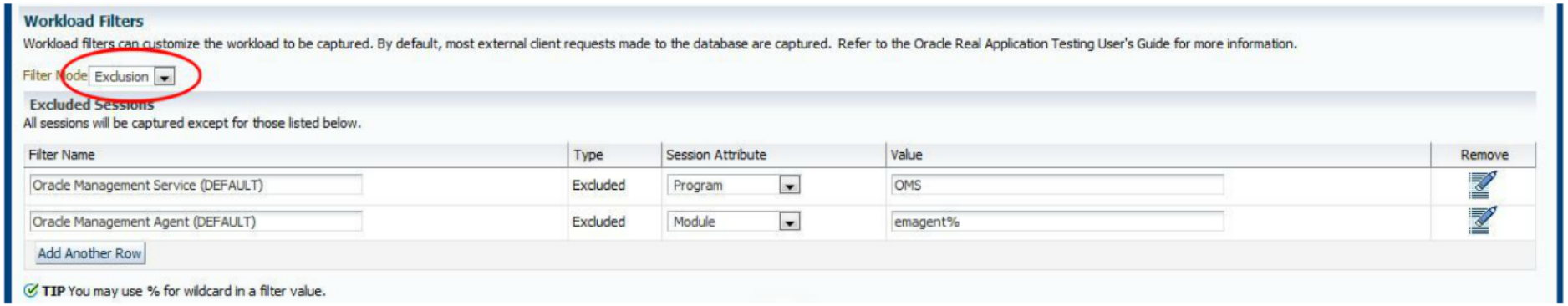
In flight transaction

- Recommendation is to stop the database instances, then start the instance(s) in restricted mode and then enable capture.
  Not possible in most cases
- It means that it can incur errors for dependent transactions
- Not an issue if errors are negligible percentage of the workload

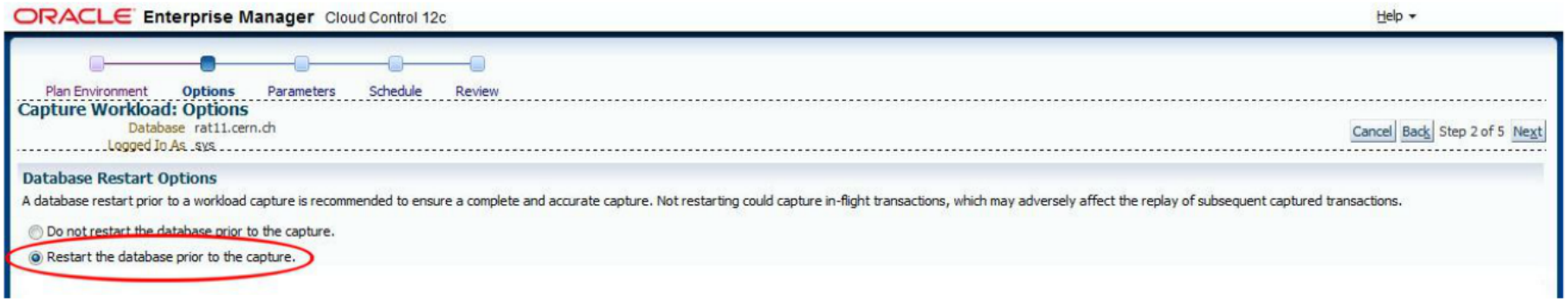


Capturing Workload

- Options
  - Workload filters

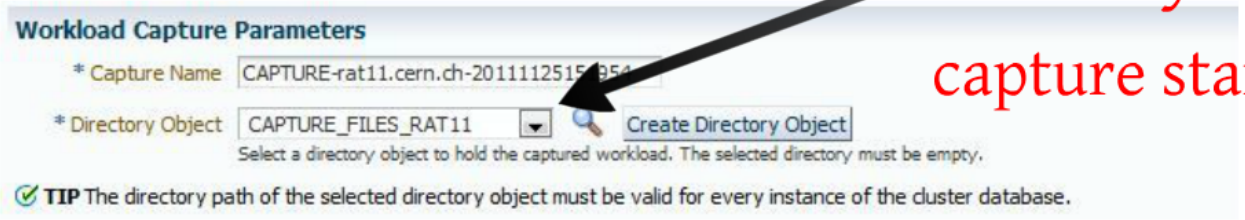


  - Database restart



Capturing Workload

- Capture
  - Capture parameters



Directory must be empty before capture start

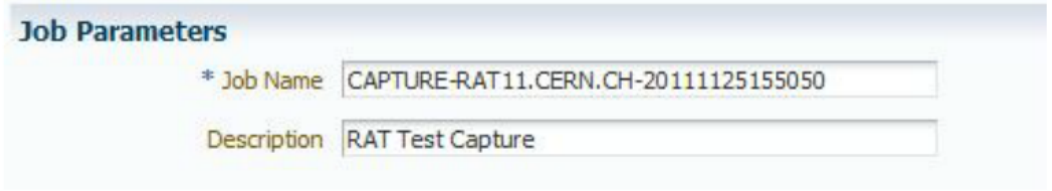
  - Shutdown/Startup parameters

The way the DB is stopped before capture start

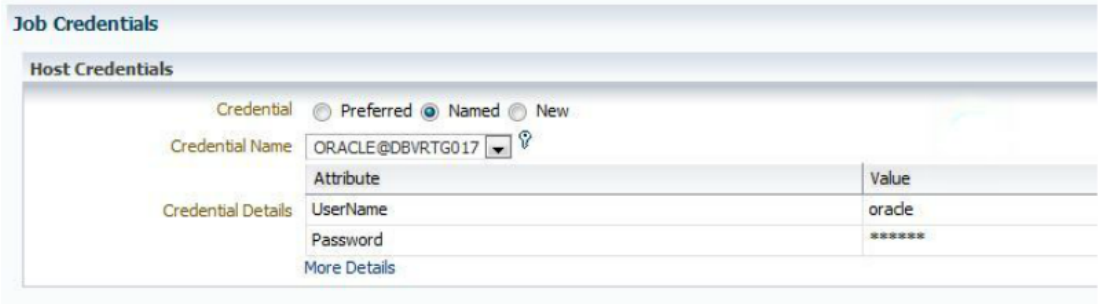
The way the DB is opened before capture start

Capturing Workload

- Scheduling capture
  - Job parameters
  - Job schedule



  - Job credentials



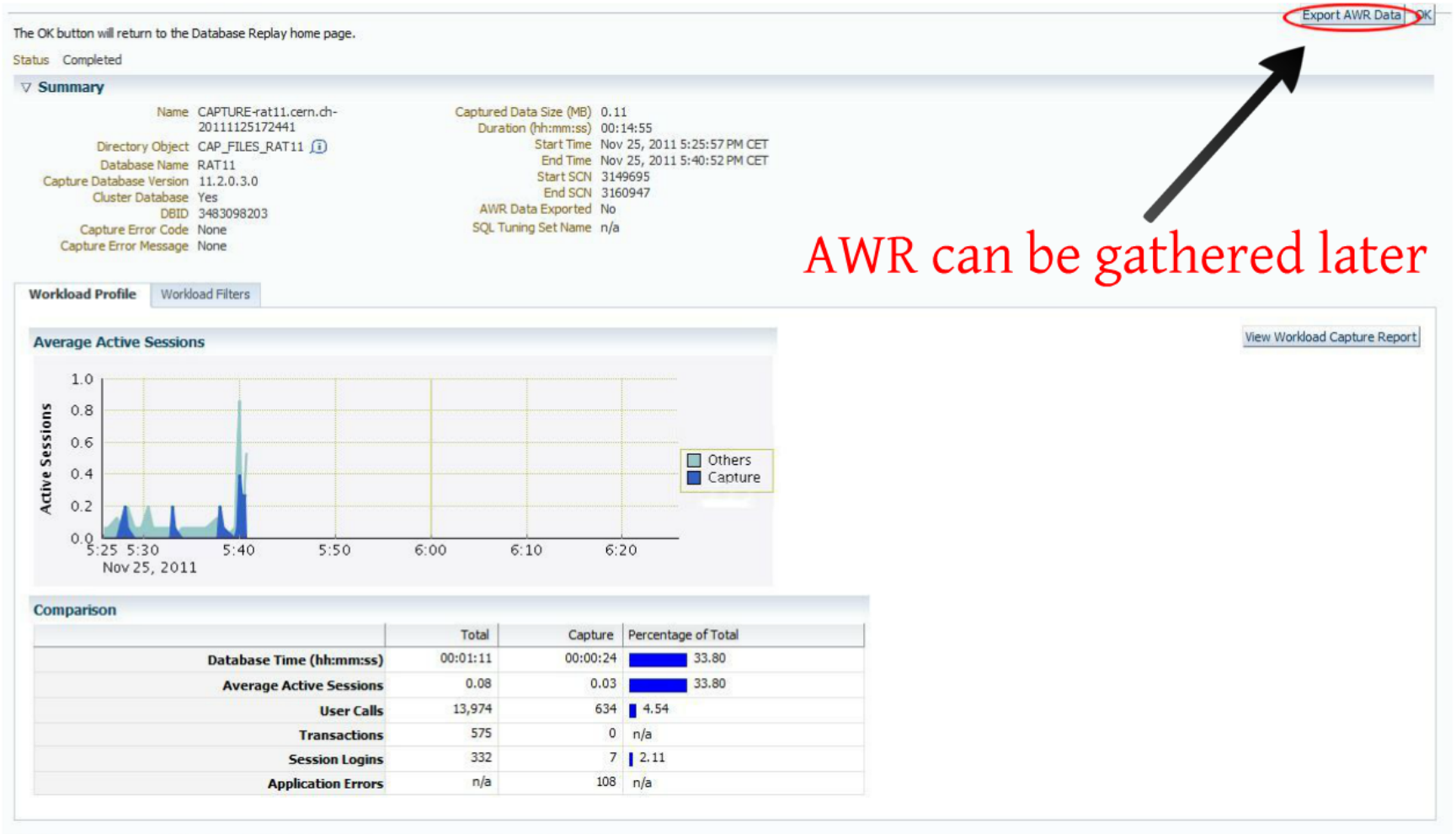
Capture will run until stopped by hand

Capturing Workload

- Reviewing settings

Capture completed

- Reviewing results



Capture results

- Capture report

Database Capture Report For RAT11

DB Name	DB Id	Release	RAC	Capture Name	Status
RAT11	3483098203	11.2.0.3.0	YES	CAPTURE-rat11.cern.ch-20111125172441	COMPLETED

Information	Capture
Start time:	25-Nov-11 16:25:57 (SCN = 3149695)
End time:	25-Nov-11 16:40:52 (SCN = 3160947)
Duration:	14 minutes 55 seconds
Capture size:	113.01 KB
Directory object:	CAP_FILES_RAT11
Directory path:	/ORA/dbs03/RPM112_TEST/CAP_FILES_RAT11
Directory shared in RAC:	TRUE
Filters used:	2 EXCLUSION filters

Captured Workload Statistics

- 'Value' represents the corresponding statistic aggregated across the entire captured
- '% Total' is the percentage of 'Value' over the corresponding system-wide aggregate

Statistic Name	Value	% Total
DB time (secs)	23.61	33.35
Average Active Sessions	0.03	
User calls captured	634	4.54
User calls captured with Errors	108	
Session logins	7	2.11
Transactions	0	0.00

DB Capture Report

- Capture Statistics
- Workload Captured
- Workload Not Captured - Contains Unreplayable Calls
- Workload Not Captured - User Filtered
- Workload Not Captured - DB Scheduler Jobs and Background Activity
- SQL Text
- Workload Filters

Workload Analyser: Capture analysis

- Java application to produce report (see references)

PL/SQL

Maximum Workload Impact: 100 % of DB Time

Rationale

If the replay is much slower than expected, try to run in unsynchronized mode.

Action

A significant part of your workload comes from PL/SQL.
If the PL/SQL blocks or functions have 'complicated' logic or multiple commits in them, they are hard to synchronize and they behavior might change during replay.
You might see a different workload profile during replay if this is the case.

SCHEDULED JOBS

Maximum Workload Impact: 40 % of DB Time

Rationale

During the capture period, a significant amount of the workload was created by scheduled jobs.
If some of these jobs were scheduled before the capture period, they have not been captured and will not be replayed.

Action

In order for their work to be done during replay, the same jobs should be scheduled to run during the replay period.

SYSDATE and other time-dependent functions

Maximum Workload Impact: 9 % of DB Time

Rationale

A significant part of your SQL workload is referencing SYSDATE.

Action

The system clock needs to be restored to its capture value before replay.

Non captured workload

Maximum Workload Impact: 5 % of DB Time

Rationale

A significant amount of the workload running during the capture period was not captured, most likely because of capture filters.

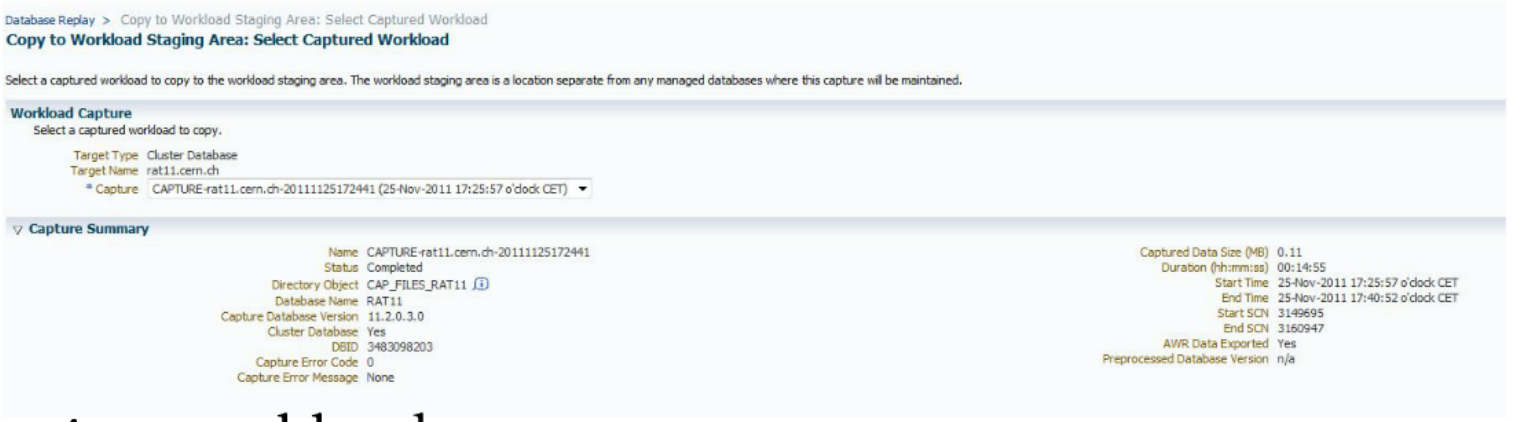
Action

This part of the workload will not be replayed and will not appear in the AWR reports.

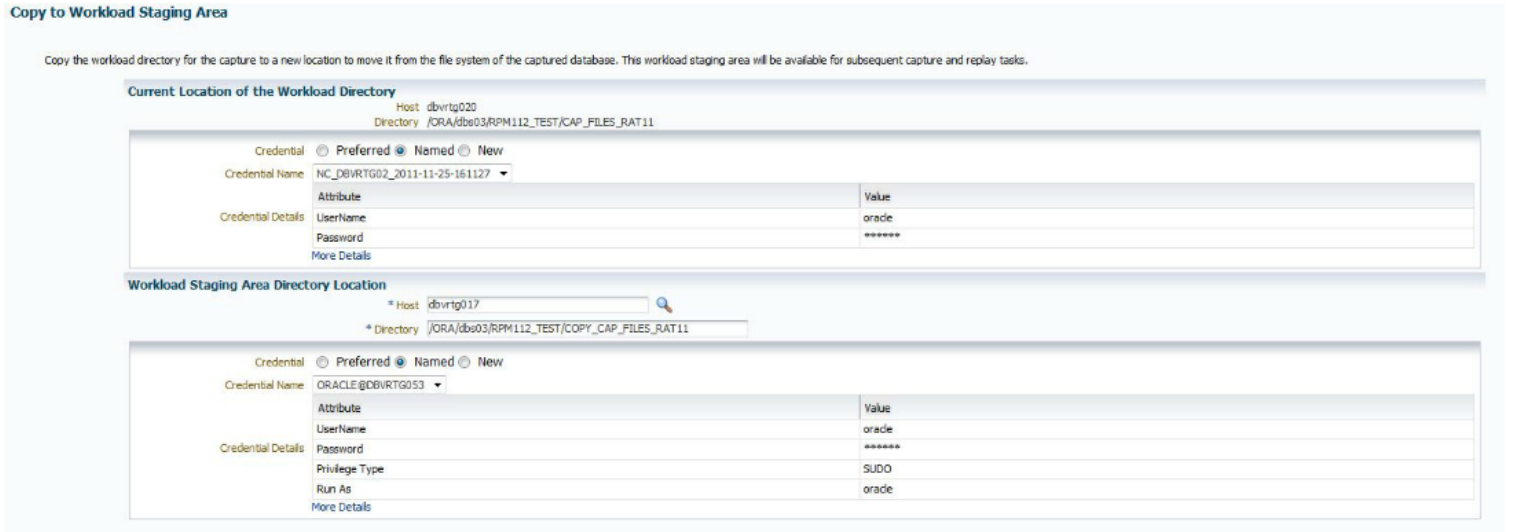
Also available in Oracle Enterprise Manager Database Control 11.2.0.2 and above

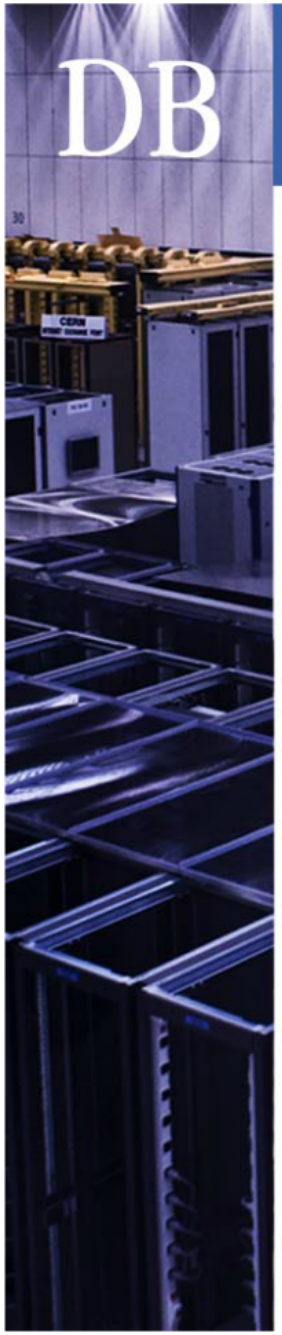
Staging workload

- Selecting workload



- Copying workload





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A closer look at Real Application Testing

- One file created per server process (each session for dedicated server process),
- Sequential, buffered writing per session

```
access("/…/wcr_7jya5h0000009.rec", F_OK) = -1 ENOENT (No such file or
directory)
open("/…/wcr_7jya5h0000009.rec", O_RDWR|O_CREAT|O_TRUNC, 0666) = 10
```

Capture files


```
$ ls -lrt /proc/7576/fd/
lrwx------ 1 oracle ci 64 Sep 20 22:06 9 ->
[…]/wcr_7jwjrh0000002.rec

$ strace -tt -T -p 7937 2>&1 | grep "write(9"
22:24:30.745968 write(9, "…"..., 4096) = 4096 <0.000028>
22:24:30.746050 write(9, "…"..., 45056) = 45056 <0.000044>
22:24:30.746149 write(9, "…"..., 684) = 684 <0.000016>

22:24:31.111495 write(9, "…"..., 4096) = 4096 <0.000026>
22:24:31.111584 write(9, "…"..., 45056) = 45056 <0.000038>
22:24:31.111675 write(9, "..."..., 713) = 713 <0.000017>

22:24:31.474120 write(9, "…"..., 4096) = 4096 <0.000027>
22:24:31.474193 write(9, "…"..., 45056) = 45056 <0.000040>
22:24:31.474282 write(9, "…"…,712) = 712 <0.000019>
```

Impact at capture time

- Measured to be less than 4-5% in all our deployments (sometimes less than 1%)
- Space and impact depends on the number of database calls with length of binds (usage of LOBs, etc.)
- Space requirements (from 340MB/hour to 2815MB/hour on some of our workloads)
  - Starting point 2 x Bytes received via SQL*Net from client

RAC and DB capture/replay

- Capture is same as for single instance
  - DBMS_WORKLOAD_CAPTURE.START_CAPTURE only once
  - alert_AISDBP1.log:DBMS_WORKLOAD_CAPTURE.START_CAPTURE(): Starting database capture at 09/26/2011 16:48:59
  - alert_AISDBP2.log:DBMS_WORKLOAD_CAPTURE.START_CAPTURE(): Starting database capture at 09/26/2011 16:48:59
  - alert_AISDBP3.log:DBMS_WORKLOAD_CAPTURE.START_CAPTURE(): Starting database capture at 09/26/2011 16:48:59
  - alert_AISDBP4.log:DBMS_WORKLOAD_CAPTURE.START_CAPTURE(): Starting database capture at 09/26/2011 16:48:59
- Replay requires that all files are accessible
- Services should be used for connection mapping
  - Actually not RAC specific

```
DBMS_WORKLOAD_REPLAY.REMAP_CONNECTION
(connection_id => XX, replay_connection =>
'(DESCRIPTION=…')
```

Considerations

- Enough WRC clients (c.f. wrc mode=calibrate)
- Job/scheduler sessions are not captured
  - Jobs will be played as “normally” (would they be captured, they would run twice!)
- Both commit and timing dependencies are preserved
  - Including the number of rows fetched, think time (includes network latency)
- Enqueue locking is preserved
  - In synchronised mode, becomes intended locking

DB replay provided reports

- DB Replay Report

Replay Statistics

Statistic	Replay	Capture
DB Time	208459.275 seconds	8507.975 seconds
Average Active Sessions	47.17	2.41
User calls	1211358	1211388
Network Time	2302270.095 seconds	
Think Time	1257596.755 seconds	

Replay Divergence Summary

Divergence Type	Count	% Total
Session Failures During Replay	0	0.00
Errors No Longer Seen During Replay	560	0.05
New Errors Seen During Replay	16887	1.39
Errors Mutated During Replay	5993	0.49
DMLs with Different Number of Rows Modified	382	0.03
SELECTs with Different Number of Rows Fetched	10076	0.83

By Divergence magnitude

(-) Hide

Max divergence magnitude	Divergence distribution (%)	Count
less rows than expected were affected	4.71	18
more rows than expected were affected	.26	1
no rows affected	95.02	363

SELECT Data Divergence

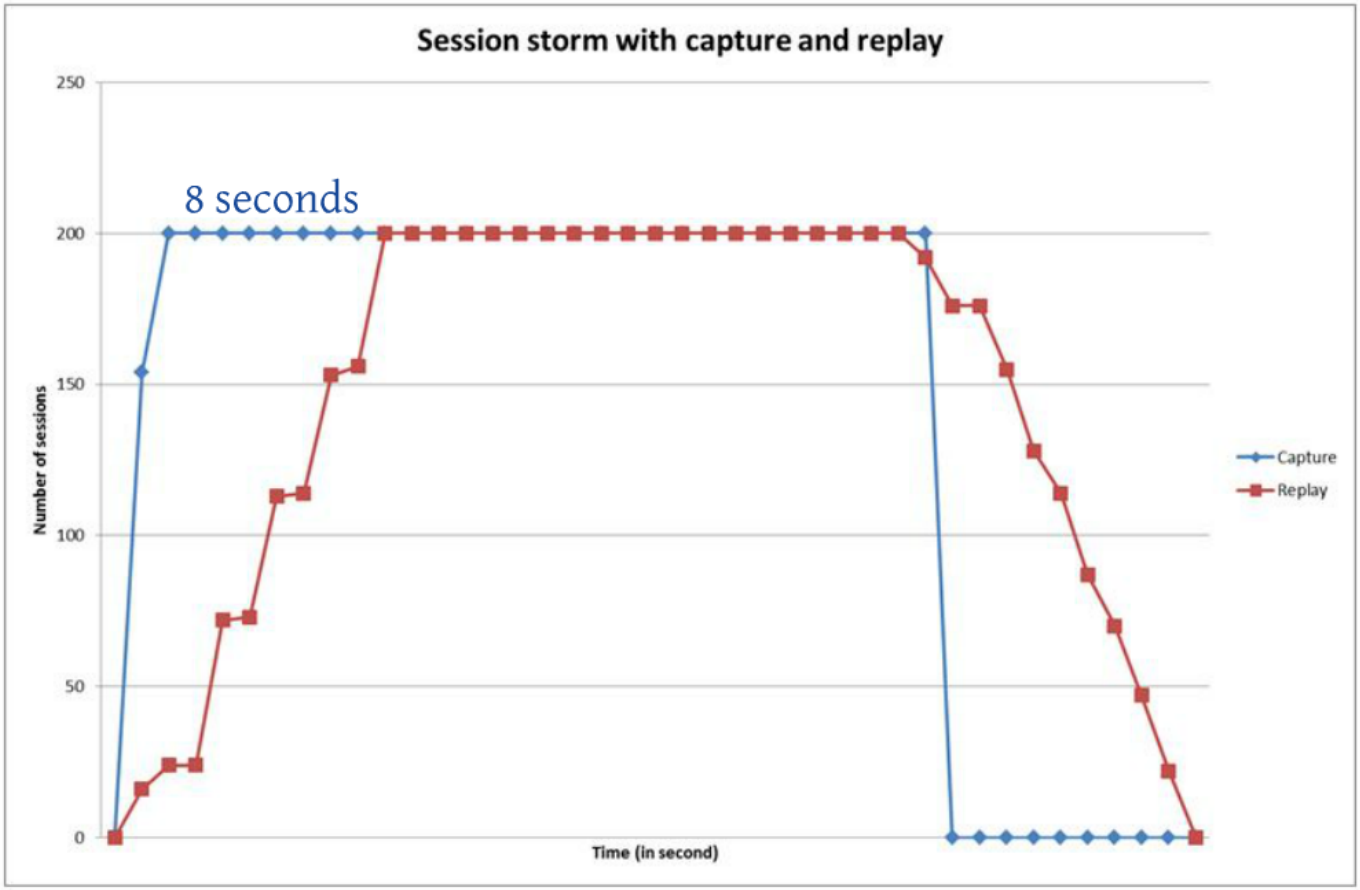
By Application

(-) Hide

Service Name	Module Name	Action Name	Avg Rows Affected	Avg Absolute Rows Affected	Number of Distinct Sessions	Count	First Occurrence	Last Occurr
AISDBP.WORLD	JDBC Thin Client	UNNAMED	-.3	1.6	36	2621	2011-10-02T01:12:12.360973+02:00	2011-10-02T02:21:58.
AISDBP.WORLD	Realtime Connection	RAC_WAIT	-8.3	8.3	1	1524	2011-10-02T01:13:21.151991+02:00	2011-10-02T02:21:58.

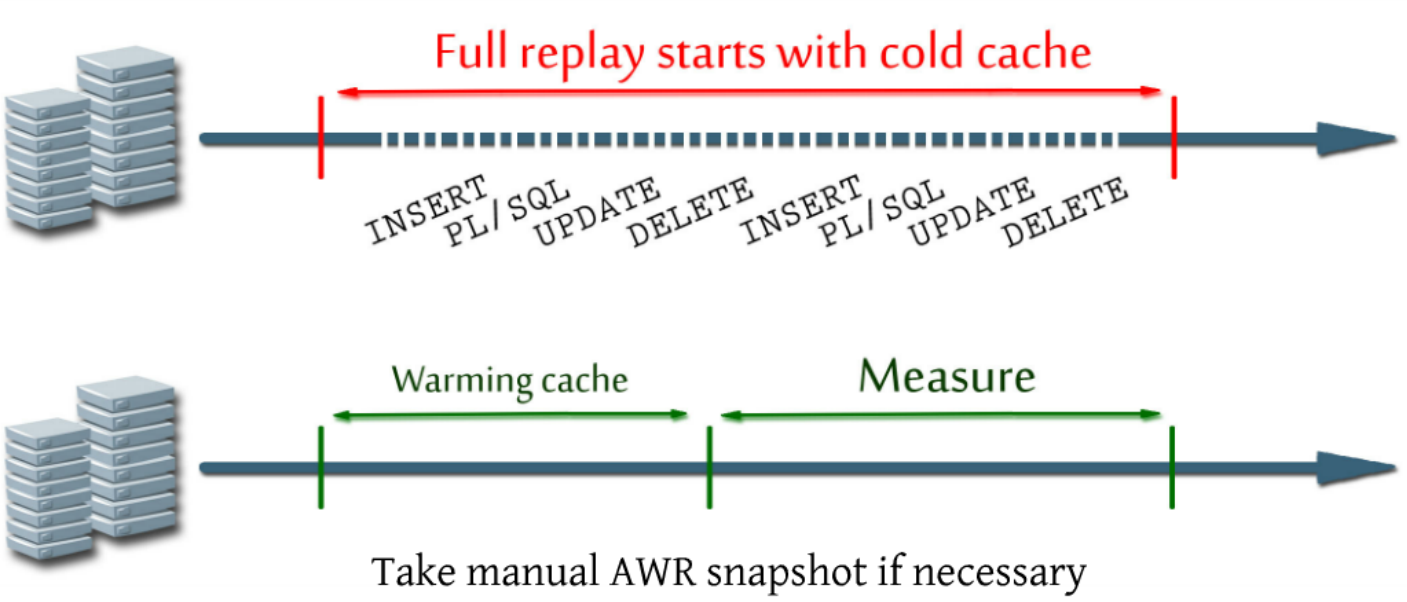
Connections of sessions

- Not exactly replayed as in capture (but not far), replay connections are ramped



Considerations

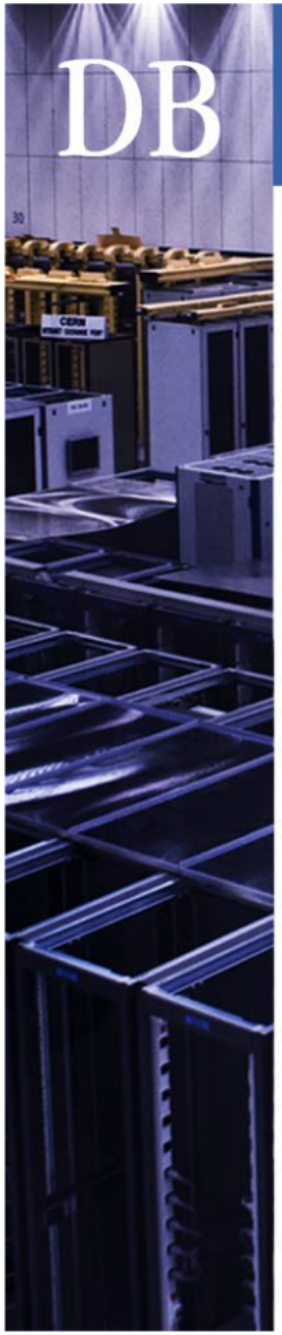
- Warming DB caches can make differences
  - Has globally less impact for long capture/replay
  - Can take the AWR reports after a first period of replay
    - And compare between this snapshot and the "end capture" snapshot
  - Also an interesting feature to assess warm-up effect



Considerations

Some limitations, to be understood to obtain the best results

- Direct path load of data from external files using utilities such as SQL*Loader
- Non-PL/SQL based Advanced Queuing (AQ)
- Flashback queries
- Oracle Call Interface (OCI) based object navigations
- Non SQL-based object access
- Distributed transactions (any distributed transactions that are captured will be replayed as local transactions)



Outline

- CERN
- Why Real Application Testing?
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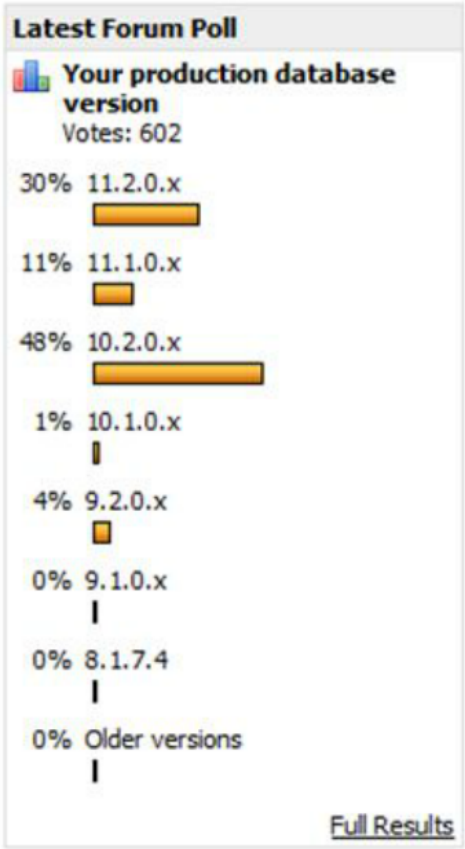
    - measure the difference,

    - ... and performance issue,
- Methodology
- Recommendations and conclusions

Upgrade with RAT

- Even more than for other operations, upgrade teams are usually making best guesses and fixing if needed.
- Downgrading may or may not be possible...
  - has compatible been incremented?
- Should we keep optimizer_feature_enable to 10.2.0.5? Memory parameters change, platform change, etc.
- Executions plan can change, ORA-600, ORA-7445, etc.



Measure the difference

- AWR based (DB time, topN statements, etc.)
  - `exec dbms_workload_capture.export_awr (capture_id => XX);`
  - `DBMS_WORKLOAD_REPOSITORY.AWR_DIFF_REPORT_HTML`
  - `select dbms_workload_capture.import_awr(capture_id => XX, staging_schema => 'XX') from dual;`

Snapshot Set	DB Name	DB Id	Instance	Inst num	Release	Cluster	Host	Std Block Size
First (1st)	ALICESTG	1368869684	ALICESTG1	1	10.2.0.5.0	YES	dbsrvc203	8192
Second (2nd)	ALICESTG	3208278054	ALICESTG1	1	11.2.0.2.0	NO	dbsrvg418.cern.ch	8192

Snapshot Set	Begin Snap Id	Begin Snap Time	End Snap Id	End Snap Time	Avg Active Users	Elapsed Time (min)	DB time (min)
1st	16945	22-Sep-11 16:00:54 (Thu)	16946	22-Sep-11 16:37:00 (Thu)	2.0	36.1	72.4
2nd	16946	24-Sep-11 19:33:18 (Sat)	16948	24-Sep-11 21:29:01 (Sat)	1.3	115.7	146.3
%Diff					*-37.0*	*220.6*	*102.2*

- Active Session History
- Graph (Enterprise Manager)
- All via reports or SQL interface

DB replay provided reports

- Compare Period Report

```
dbms_workload_replay.COMPARE_PERIOD_REPORT(replay_id1=>1,replay_id2=>null,format=>dbms_workload_replay.type_html,result=>vblob);
```

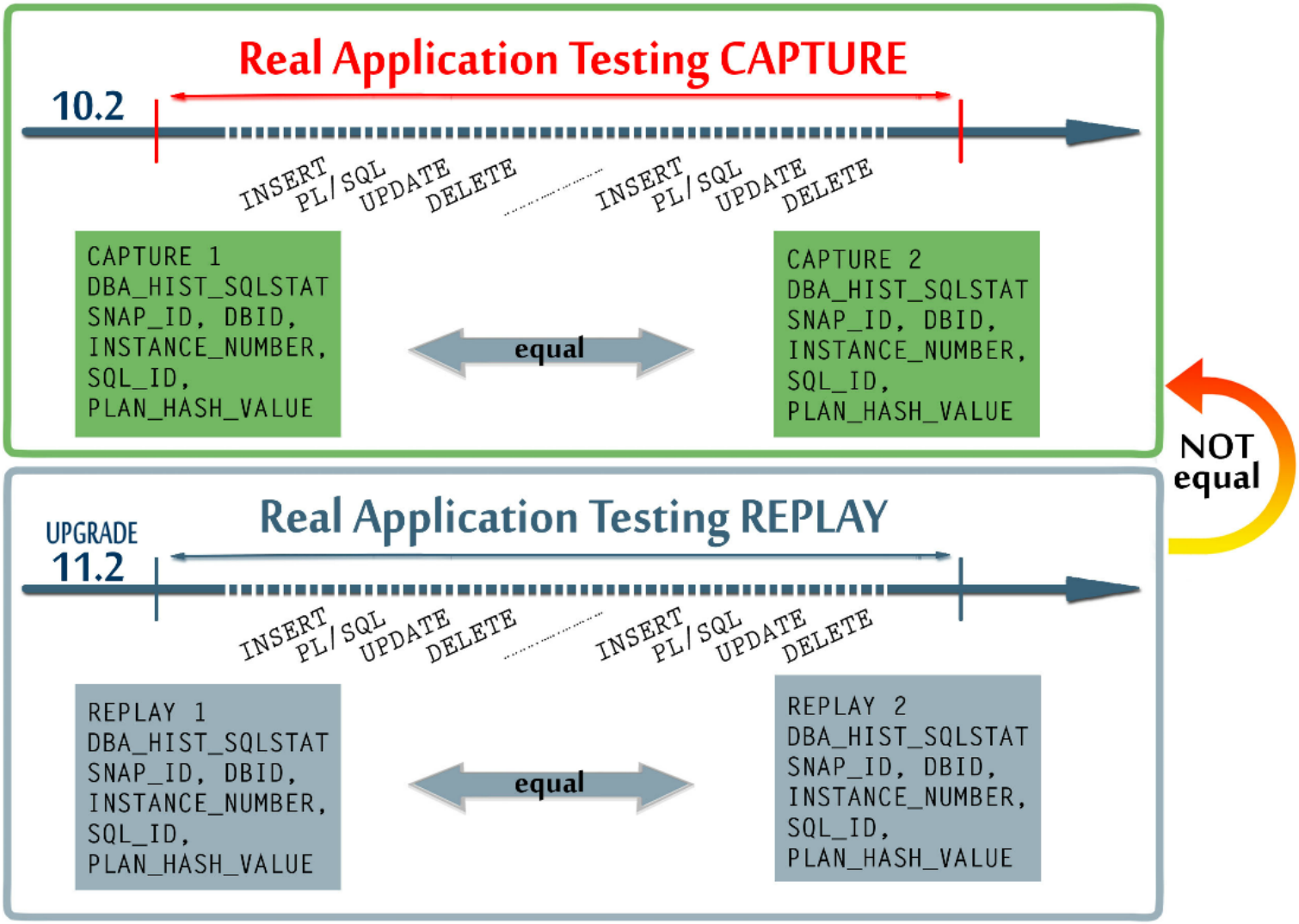
(-) Changes to Important Parameters

	Capture	Replay
processes	1500	1300
sessions	1655	1976
open_cursors	1024	800
compatible	10.2.0.1.0	10.2.0.5
cluster_database	TRUE	FALSE

(-) Changes to Optimizer-Relevant Parameters

		min	average	max
pga_aggregate_target	Capture	1 G	2.5 G	3 G
	Replay	450 M	450 M	450 M
optimizer_capture_sql_plan_baselines	Capture	NULL		
	Replay	FALSE		
optimizer_use_invisible_indexes	Capture	NULL		
	Replay	FALSE		
optimizer_use_pending_statistics	Capture	NULL		
	Replay	FALSE		
optimizer_use_sql_plan_baselines	Capture	NULL		
	Replay	TRUE		
optimizer_features_enable	Capture	10.2.0.5		
	Replay	11.2.0.2		
query_rewrite_enabled	Capture	TRUE		
	Replay	true		
query_rewrite_integrity	Capture	enforced		
	Replay	trusted		
result_cache_mode	Capture	NULL		
	Replay	MANUAL		
workarea_size_policy	Capture	AUTO		
	Replay	auto		

SQL with different exec plans



SQL with different exec plans


```
select * from
(select distinct c1.sql_id, c1.PLAN_HASH_VALUE, c1.parsing_schema_name from
DBA_HIST_SQLSTAT C1, DBA_HIST_SQLSTAT C2
where c1.dbid=c2.dbid and c1.dbid=1523625663
and c1.snap_id=86777 and c2.snap_id=86779
and c1.sql_id=c2.sql_id and c1.parsing_Schema_name=c2.parsing_schema_name) c,
(select distinct r1.sql_id, r1.PLAN_HASH_VALUE, r1.parsing_schema_name from
DBA_HIST_SQLSTAT r1, DBA_HIST_SQLSTAT r2
where r1.dbid=r2.dbid and r1.dbid=2416127519
and r1.snap_id=86902 and r2.snap_id=86904
and r1.sql_id=r2.sql_id and r1.parsing_Schema_name=r2.parsing_schema_name) r
where c.parsing_schema_name=r.parsing_schema_name and c.sql_id=r.sql_id and
c.PLAN_HASH_VALUE<>r.PLAN_HASH_VALUE;
```

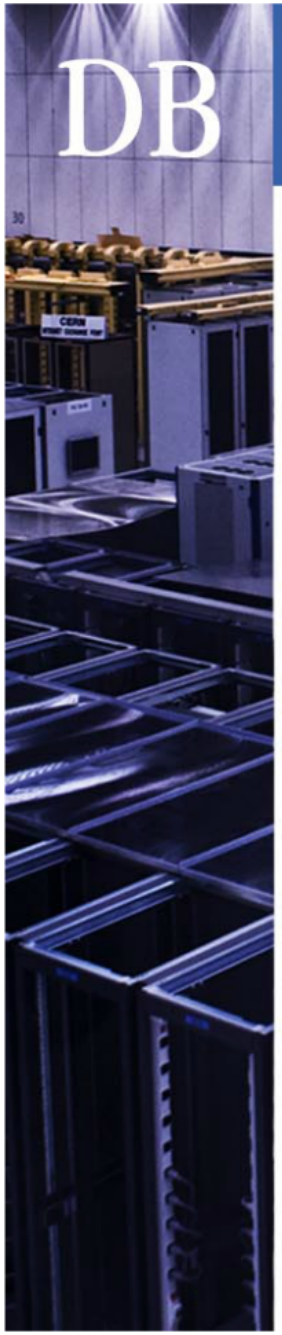
SQL_ID	PARSING_SCHEMA_NAME	PLAN_HASH_VALUE	PLAN_HASH_VALUE
az33m61ym46y4	TOOLS_BAMBOO	65779599	1787062016
12qas01c7u7b2	APPT	567743951	4264701941
2y8gak7yksxcv	EGEE3	2855226907	371117825
dp4u6xqb5qssw	NAVIGATOR	3515771902	1824466124
1zv8vch4az8w6	NAVIGATOR	3515771902	1824466124
81dp53j6d2f0h	IM	2626905313	1266761433
g1tvm117sp2pw	CERN_DBA	2325995021	2571336381

AWR_DIFF_REPORT_HTML

Top SQL Comparison by Elapsed Time

- Ordered by absolute value of 'Diff' column of 'Elapsed Time % of DB time' descending
- '#Plans' column indicates the number of distinct execution plans for the statement in 1st and 2nd periods and in Both periods combined
- '1st Total' and '2nd Total' show respective running totals for '1st' and '2nd' columns of 'Elapsed Time % of DB time'
- DB time First: 1,336.19 seconds, Second: 102,678.37 seconds
- Captured SQL Elapsed Time First: 777.66 seconds, Second: 2,687.68 seconds
- Captured SQL Elapsed Time as a % of DB time First: 58.2%, Second: 2.62%
- Captured PL/SQL Elapsed Time as a % of DB time First: 47.31%, Second: .56%
- Common SQL Elapsed Time as a % of DB time First: 4.79%, Second: .36%

	Elapsed Time % of DB time					Elapsed Time (ms) per Exec		#Exec/sec (DB time)		CPU Time (ms) per Exec		I/O Time (ms) per Exec		Physical Reads per Exec		#Rows Processed per Exec		#Executions		#Plans	
SQL Id	1st	1st Total	2nd	2nd Total	Diff	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st/2nd/Both	SQL Text
94vzsmtv6uwq1	22.81	22.81			-22.81	304,757		0.00		304,820		78		9.00		1.00		1			DECLARE job BINARY_ ...
5up45xw1tb59g	21.89	44.69			-21.89	292,444		0.00		287		493		44.00		0.00		1			BEGIN DBMS_WORKLOAD_C
21xrj10nz3psp	11.53	56.22			-11.53	154,008		0.00		156,845		78		9.00		136,948.00		1		1// 1	INSERT /*+ BYPASS_RECURSIVE_
cbwrqyq0dau4j	10.12	66.34			-10.12	135,281		0.00		138,038		0		0.00		3,097.00		1		1// 1	INSERT /*+ BYPASS_RECURSIVE_
ftj6kv3h81tj7	9.01	75.36			-9.01	120,447		0.00		10		0		0.00		2.00		1		1// 1	SELECT * FROM INFORJMTFEEDBACK..
2nq0v7pfu8um7	3.42	78.78			-3.42	0		274.33		0		0		0.00		1.00		366,560		1// 1	SELECT SUM(NVL(D.W 1)*SU...
dp4u6xqb5qssw	2.76	81.54	0.12	0.12	-2.65	15	56	1.85	0.02	15	51	0	2	0.00	0.45	0.87	0.87	2,471	2,118	1/ 1/ 2	select login_as from im
0az7czjdw8z7j	1.50	83.04			-1.50	4,007		0.00		2,691		152		0.00		0.00		5			declare lbRec dbms_rc
dx1yysc93jtyq	1.43	84.48			-1.43	0		59.98		0		0		0.00		1.00		80,150		1// 1	SELECT NVL(SUM(D.W



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Methodology

- Once you have a base capture/replay which is reproducing well enough the workload

1. Replay and gather comparative information between capture and replay

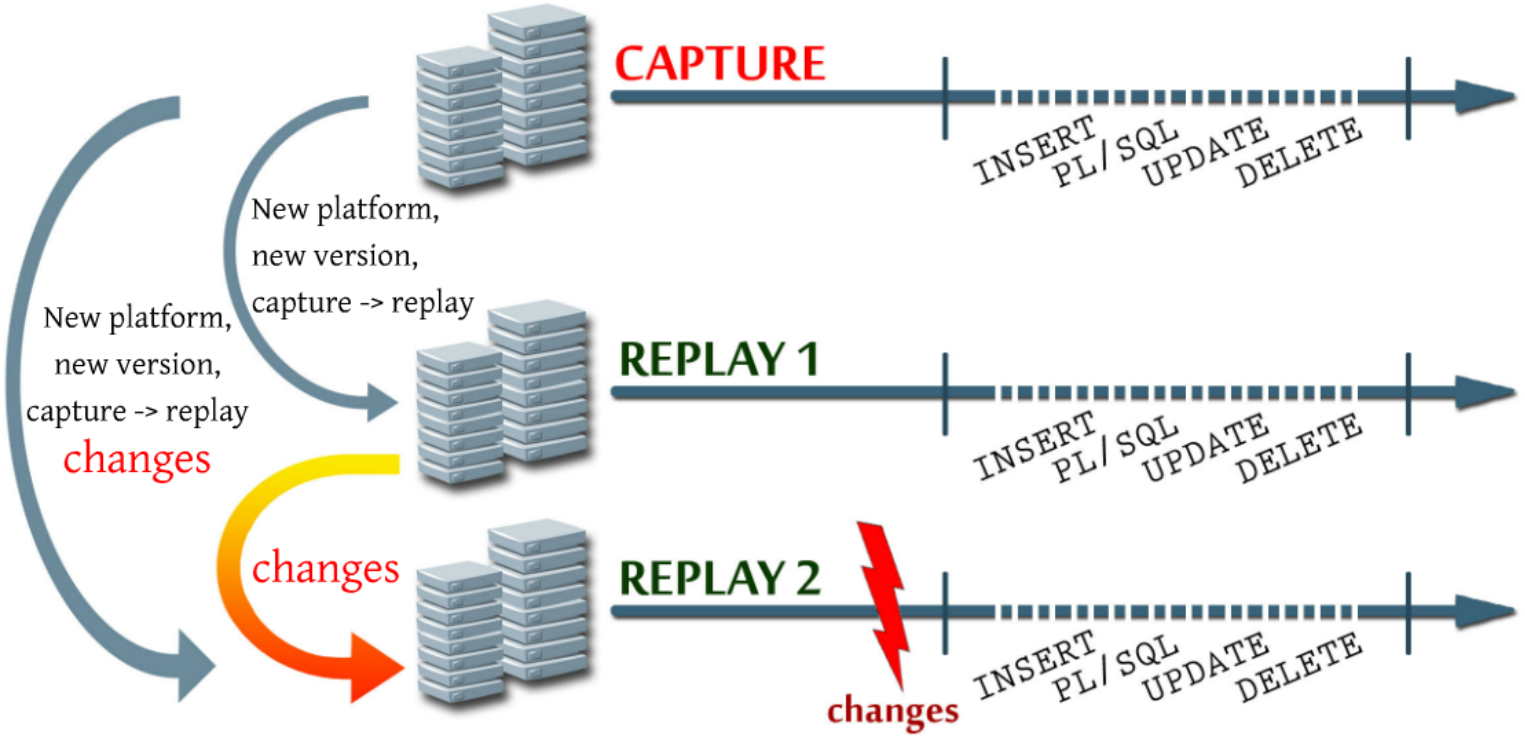
2. Identify inadequate performance or results

3. Understand root cause for the inadequate performance or results

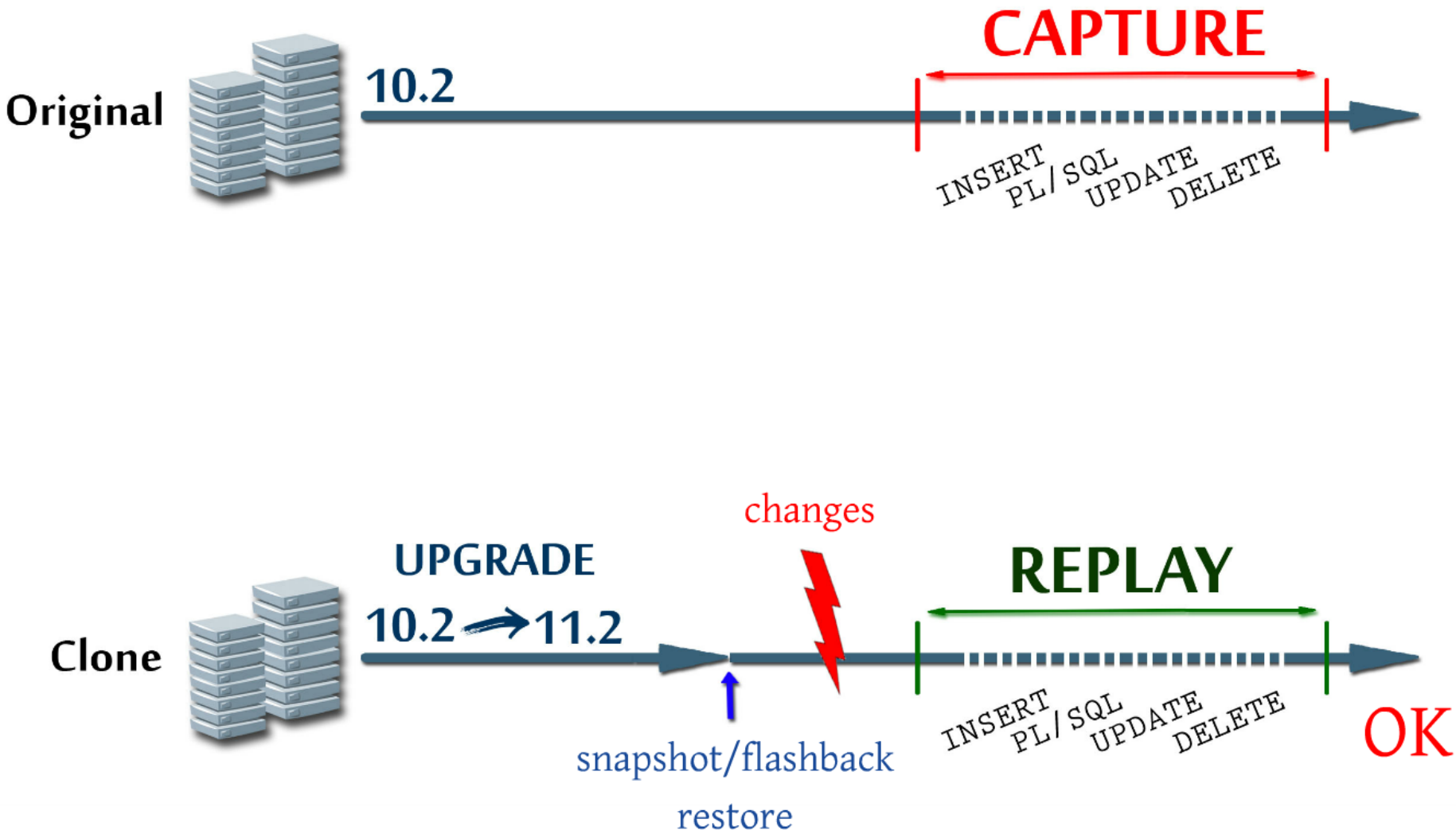
4. Modify configuration (path, SQL execution plan, etc.)

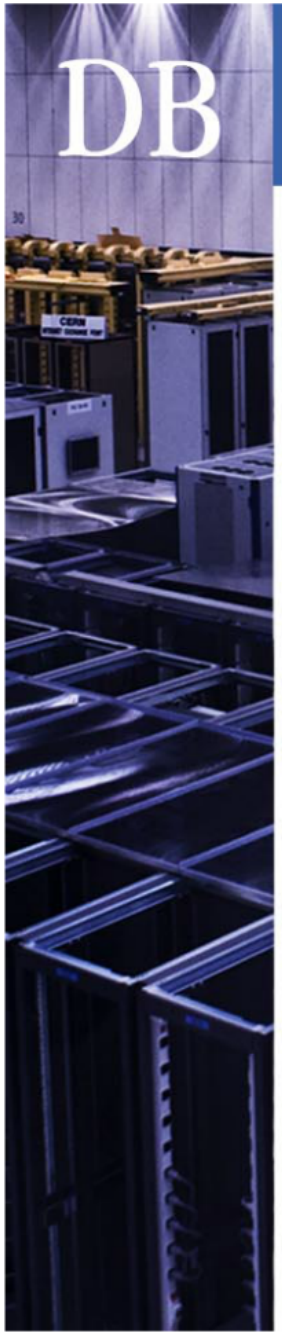
Several replays

- Advise to compare between replays when doing multiple changes and replay versus the capture (same version, measure only the differences not the capture/replay differences)



Making use of storage snapshots





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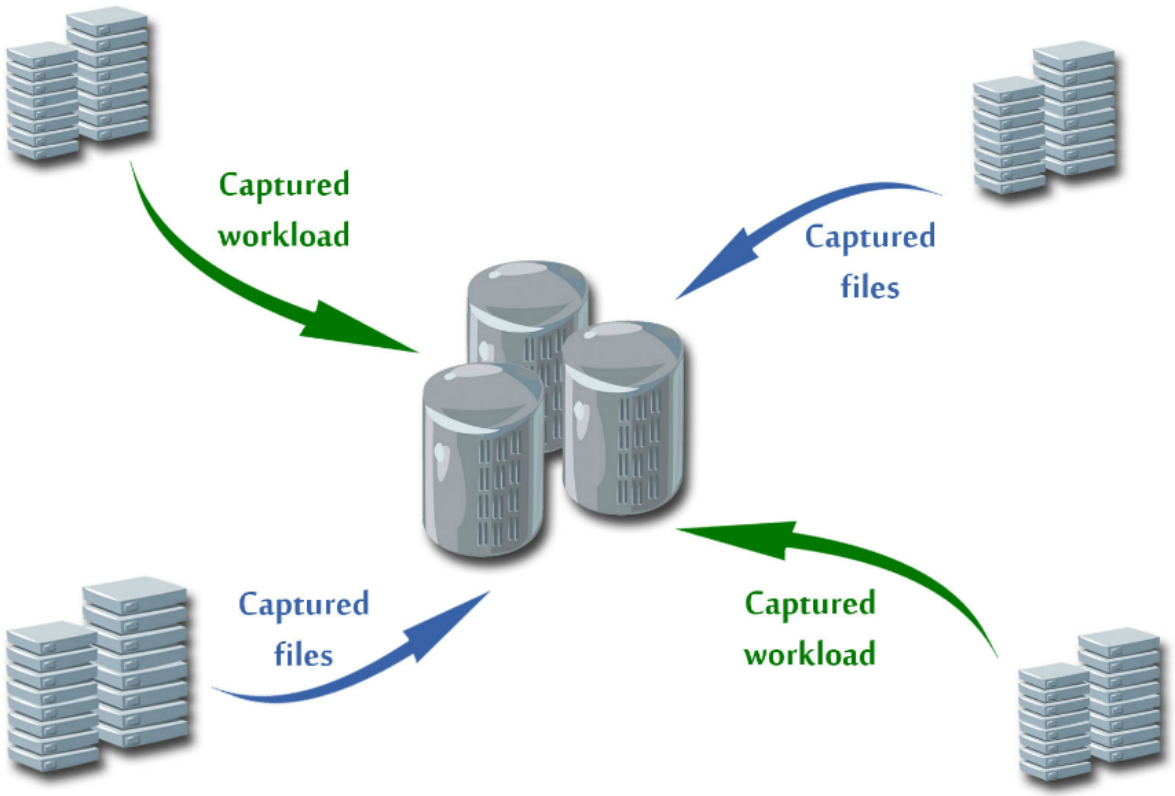
Recommendations

- Start small for capture (space/IOPS)
- Understand the job model
- Understand date/time model
- Consider length for capture and replay?
  - Ensure adequate warm-up...
- Do not capture everything (backup, EM, etc.)
  - More errors in replay, more difficult to identify fixes to be made

Central capture repository

- Following Oracle idea with Staging Area we can create central capture workload repository,
- Gather captured workload from your Production databases



Conclusions

- Not only for upgrades!
- The feature developers and DBA's have been dreaming about to avoid upgrade crisis
  - The end of synthetic workloads
- Good integration inside Enterprise Manager makes it easy to use (full PL/SQL API also available)
- In most cases, a turn-key solution
  - Some workload considerations: enough bandwidth/IOPS for caputre files, OS date/time, relevant SQLs not excluded (use Workload Analyzer)
- Enables DBA/developers to identify issues in many cases

Questions

References

- Oracle Real Application Testing
  http://www.oracle.com/us/products/database/options/real-application-testing/index.html
- My Oracle Support note Real Application Testing Now Available for Earlier Releases [ID 560977.1]
- VLDB and ACM papers on database replay
  http://www.vldb.org/pvldb/2/vldb09-588.pdf and
  http://dl.acm.org/citation.cfm?id=1376732
- Simora http://www.scaleabilities.co.uk/index.php/Simora/Introduction.html
- Replay analyser
  http://www.oracle.com/technetwork/database/focus-areas/manageability/db-replay-analyzer-172990.html