

SQLskills Immersion Event

IE3: High Availability & Disaster Recovery

Module 3: Backup Strategy and Internals

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**NOTE: Includes whiteboard drawings from prior IE3 deliveries
+ drawings done the week of May 13, 2013
Chicago, IL – IE3 Training**

B/R

Online

non det. time of
restore

Only get "used"
Space

Rolling/online/upgrade

Detach

Offline

attach is exactly
when taken ~~off~~ online

potentially lots of
free space to move

Update stats?

update stats
TPE? neither will compress well

This was from a side discussion on backup/restore vs. detach/attach. The most important two items (IMO) for why B/R is better – you have a backup ☺ and you can do this without taking the database offline. Be careful using detach/attach as it might be a one way street.

This is a pretty good pros/cons list: <http://strictlysql.blogspot.com/2011/10/backuprestore-vs-detach-attach.html> and Aaron Bertrand also did an interesting post here: http://sqlblog.com/blogs/aaron_bertrand/archive/2011/01/21/downgrading-a-database-you-can-t-get-there-from-here.aspx.

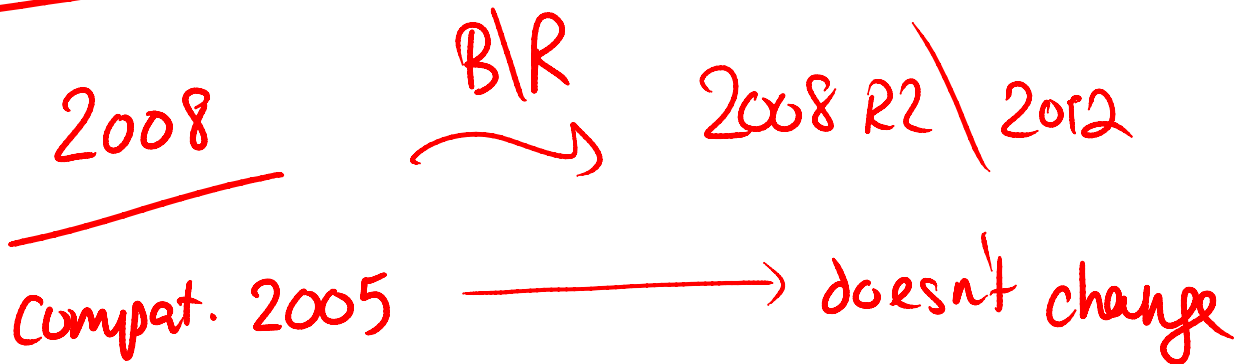
Backward Compatibility Levels

The following drawings discussed our tangent about backward compatibility levels.

The key points:

- The compat mode of the database when backed up is what will get restored. If the database compatibility mode is set to 6.5 (for example) on a 7.0 server and then backed up – the database's compat mode is 6.5. If this backup (a 7.0 database backup) is restored on SQL Server 2000 (8.0) then it will be restored and the database itself will be converted to an 8.0 database. However, the database compatibility mode will still be 6.5.
- Compat modes do not impact features, they impact parsing and keyword use. They are meant as a way to allow you to upgrade to the new release while having time to “fix” code – to remove keywords, etc.
- Setting compat modes can be done through the UI or the syntax. Often, the UI is limited in the modes available. For example, even on SQL Server 2005 (9.0) you can still set 6.5 and 6.5 – but not through the UI. Always check the syntax for setting compat modes:
 - Use `ALTER DATABASE` to set compatibility mode
 - For backward compatibility, you can still use `sp_dbcmtlevel`.

Compat



Backup/restore is supported “up-level” only and only 2 versions. However, 2008 R2 is not counted in the two version restriction. For example, you can restore from:

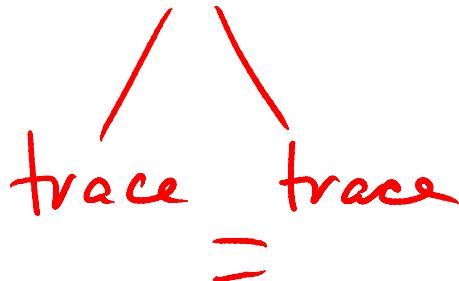
- 2000 to 2005/2008/2008R2
- 2005 to 2008/2008R2/2012

But, not from 2000 to 2012.

The compat mode of the backed up database is the compat mode that’s restored (unless no longer supported).

Upgrade advisor

Upgrade assistant



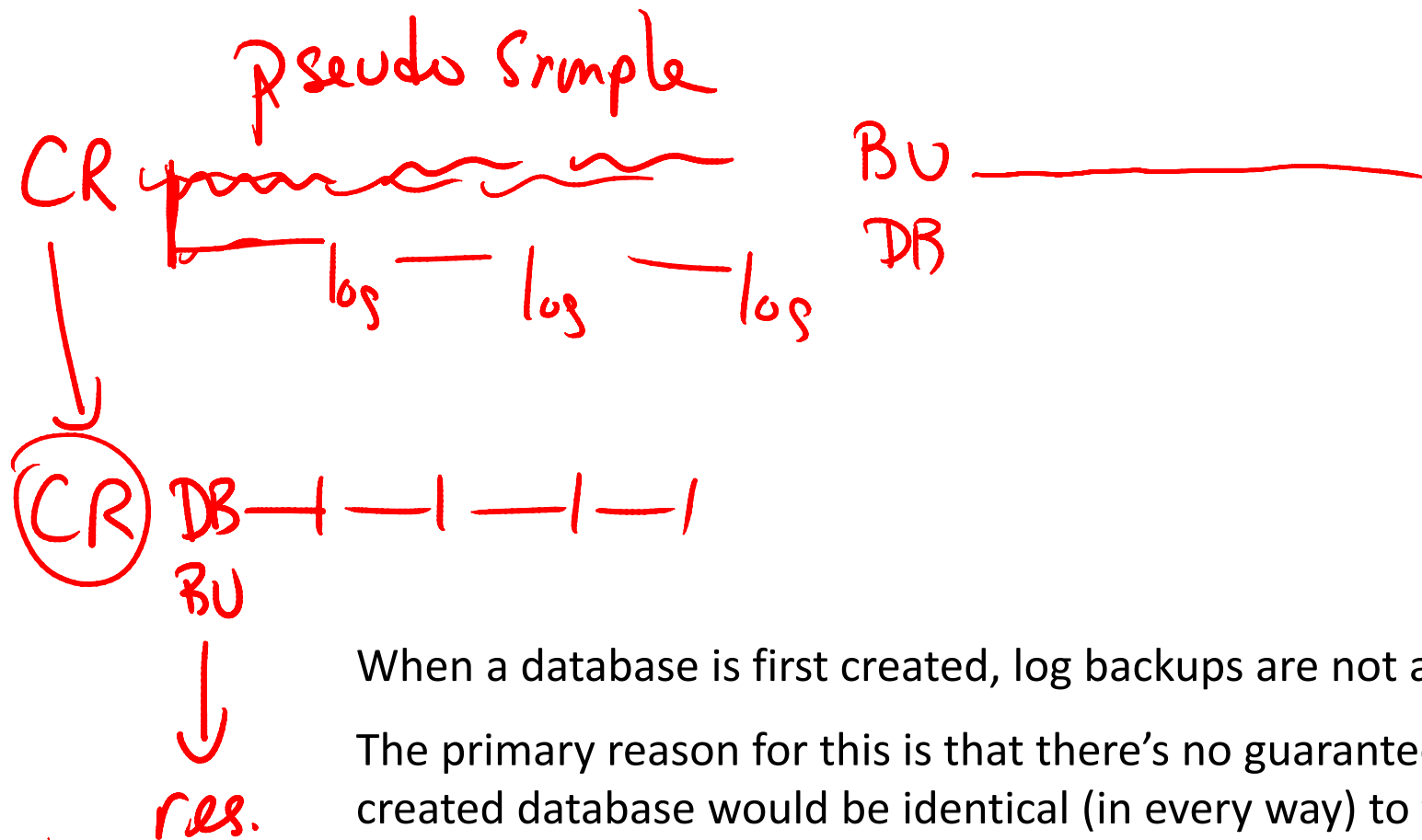
From SQL 2012 BOL: When a database is upgraded to SQL Server 2012 from any earlier version of SQL Server, the database retains its existing compatibility level ***if it is at least 90.*** Upgrading a database with a compatibility level below 90 sets the database to compatibility level 90. <http://technet.microsoft.com/en-us/library/bb510680.aspx>

Tools to help you upgrade: ?

Microsoft Upgrade Advisor: (found within the feature pack) <http://www.microsoft.com/en-us/download/details.aspx?id=29065>

Upgrade Assistant Tool for SQL Server 2012 (en-US):

<http://social.technet.microsoft.com/wiki/contents/articles/2558.upgrade-assistant-tool-for-sql-server-2012-en-us.aspx>



When a database is first created, log backups are not allowed.

The primary reason for this is that there's no guarantee that the newly created database would be identical (in every way) to the database as it was originally created. So, when a database is created it runs in the pseudo-simple recovery model. This is where the log is cleared on checkpoint. There's no reason to keep it, it cannot be backed up.

However, once you do your first database backup, the full recovery model can be leveraged and therefore the log no longer clears...

This is the reason that some folks end up with a GIANT transaction log when they've only been performing full backups.

10GB DATA \ HUGG LOG (961 GB)

In Full what to do?

if BU 1TB?

Switch to simple (clears the log)

— [Full backup (only backs up data not free space)
Switch back Full?

Fix log size (shrinkfile)

BU 10GB \ 20GB log

What do you do if you have a transaction log that's grown wildly out of control?

Switch to simple to clear the log

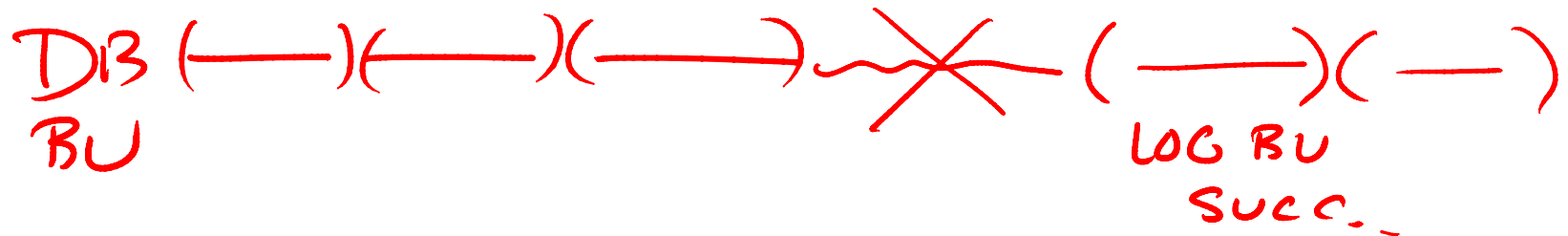
Perform a full database backup

Consider switching back to FULL (if you're going to perform log backups) OR stay in SIMPLE.

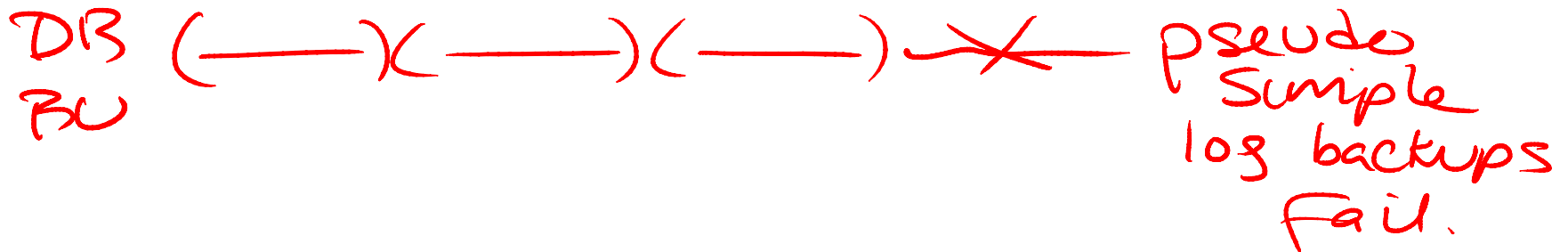
Fix the log size (DBCC SHRINKFILE)

Do another backup? Or, at least a log backup (if you're in FULL)

2000



2005



SQL Server 2000 allows the transaction log to be backed up even after the continuity of the log has been broken... Don't let this happen use trace flag 3231 to disable NO_LOG and TRUNCATE_ONLY for the log.

SQL Server 2005 sets the database back to a pseudo-simple recovery model after the continuity of the log has been broken. But, they still ALLOW the continuity of the log to be broken. Use trace flag 3231 OR 3031 to stop this from happening.

SQL Server 2008 does not allow manual clearing of the log. The NO_LOG and TRUNCATE_ONLY syntax has been deprecated.



Here we were discussing how log backups can occur concurrently with full database backups. They can even run numerous times during a single full. Each log backup will run but it will NOT clear the log. When the backup completes the data copy phase, the necessary log information will be backed up as well. This will allow the no-longer-needed log information to be cleared but it is not the full backup that caused the log to clear – it's the log backups that have already been done!

Also, if a full backup becomes damaged, SQL Server can use the logs as if the full backup had never occurred. The restore process would be:

- Use the most-recent (but working 😊) full database backup

- Use the last differential based on that full backup

- Use any logs from the last differential and until current (up-to-the-minute)

VLF Fragmentation

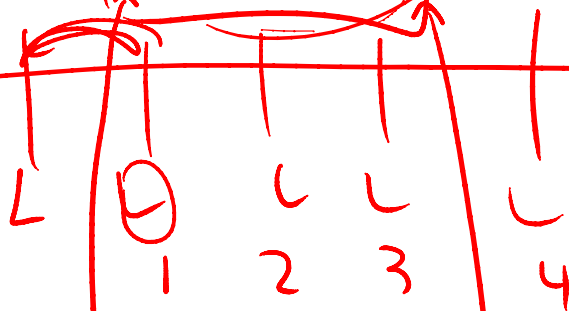
We briefly discussed VLFs (covered in IE1), here are the relevant links:

- Kimberly's blog post *"8 Steps to better Transaction Log throughput"*
 - <http://www.sqlskills.com/blogs/kimberly/post/8-Steps-to-better-Transaction-Log-throughput.aspx> (<http://bit.ly/67DFtV>)
- Beware of exactly 4GB growth/auto-growth bug
 - <http://www.sqlskills.com/BLOGS/PAUL/post/Bug-log-file-growth-broken-for-multiples-of-4GB.aspx> (<http://bit.ly/c3QQLr>)
 - Fixed in 2008 R2: <http://support.microsoft.com/kb/2633151>

2000

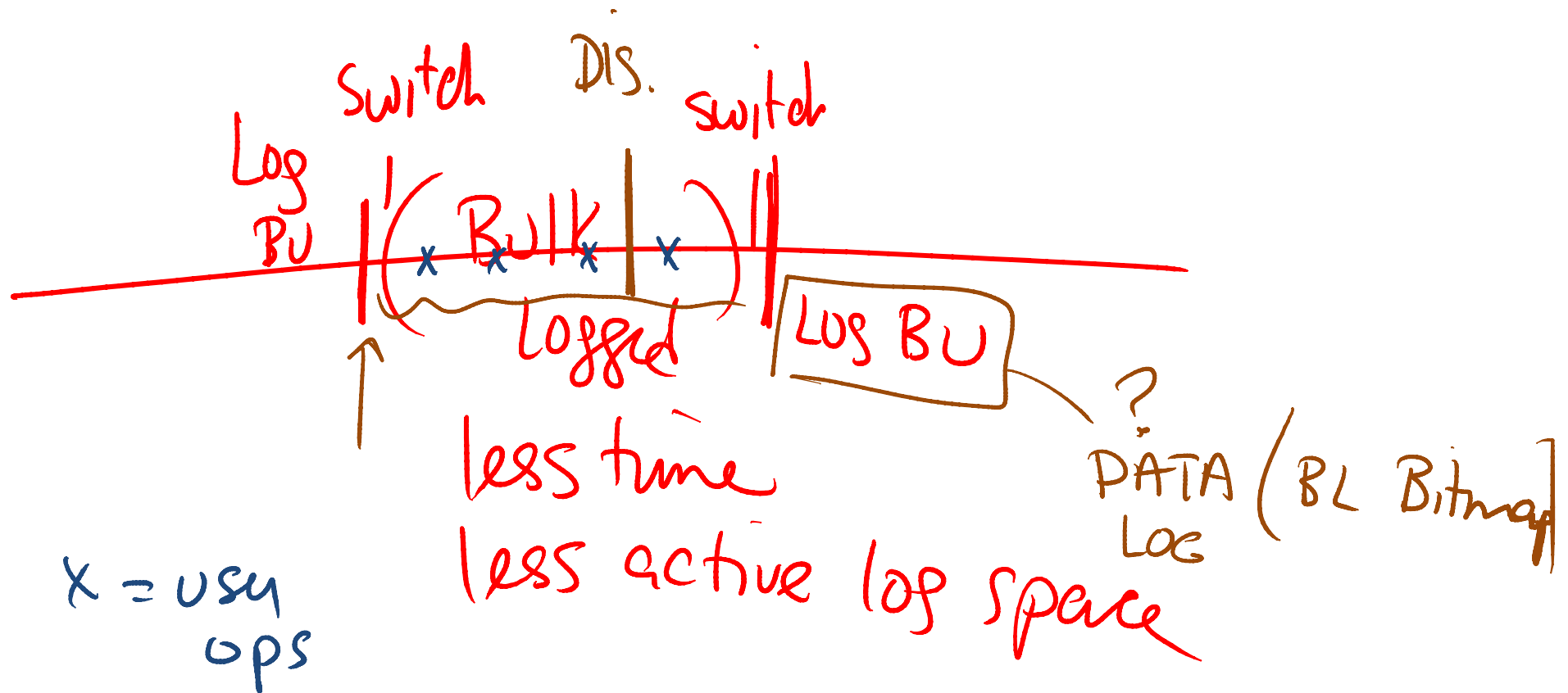
~~NO RECOVERY~~

=



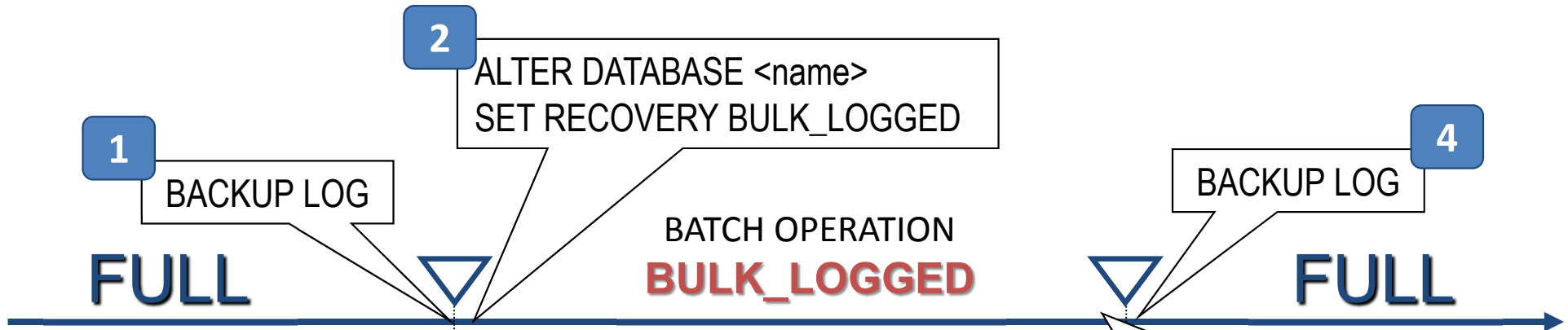
LSN
MIN

In SQL Server 2000, log backups could NOT occur concurrently with full database backups. However, log backups COULD occur concurrently with FILE or FILEGROUP backups. As a result, you could replace your full database backup strategy with FILEGROUP backups (and you have to backup ALL files/filegroups) and never have to stop your log backup job. This also meant that your secondary sites would NOT fall far behind (because log backups would NOT be blocked during FILE/FILEGROUP backups).



If you plan to use the BULK_LOGGED recovery model during certain batch/bulk operations, you should be sure to minimize the potential data loss by performing log backups before the change TO bulk_logged as well as AFTER the change back to the FULL recovery model. Remember, if a disaster were to occur while SQL Server is in BULK_LOGGED you cannot access the tail of the log (if any bulk operations have occurred). This is what you would lose if there were a disaster during the batch process.

Switching Recovery Models



Advantages:

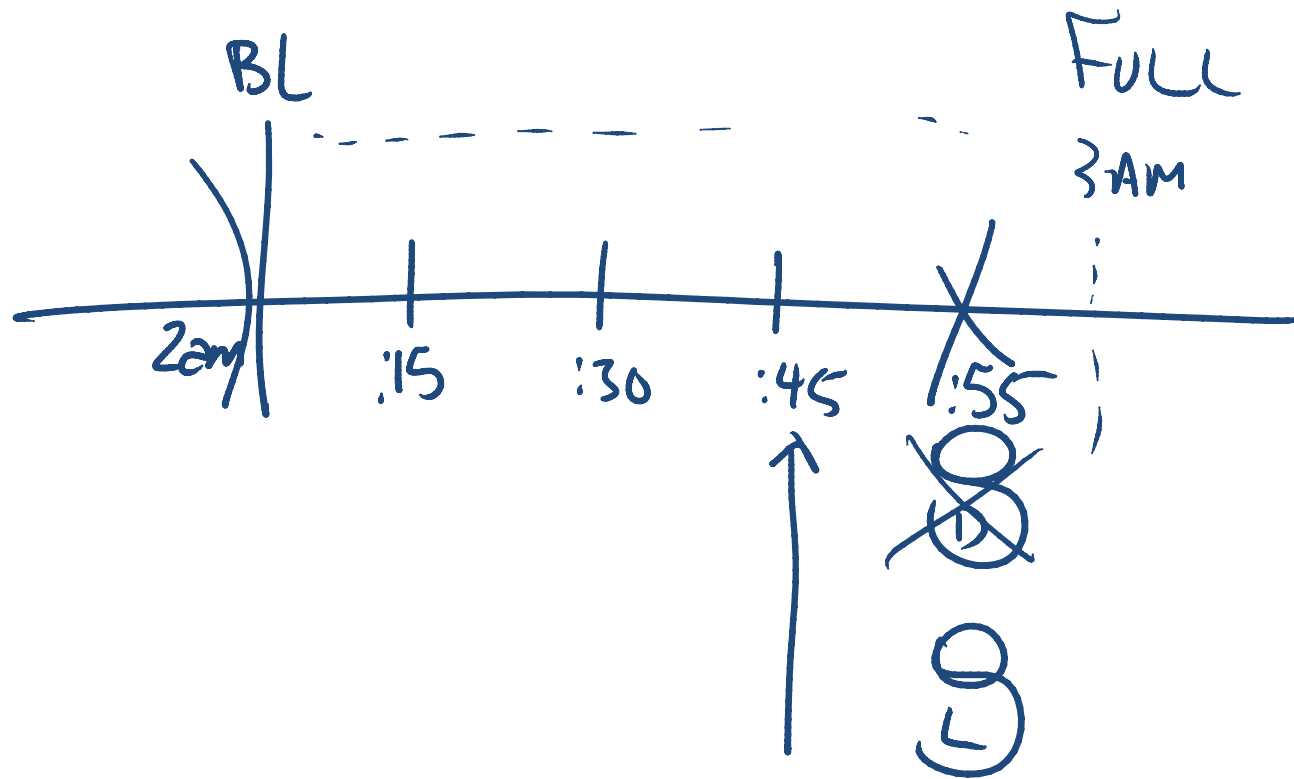
- Up-to-the-minute recovery
- Point in time recovery
- Access to “tail” of the log

Advantages:

- Minimal logging
- Faster bulk operation

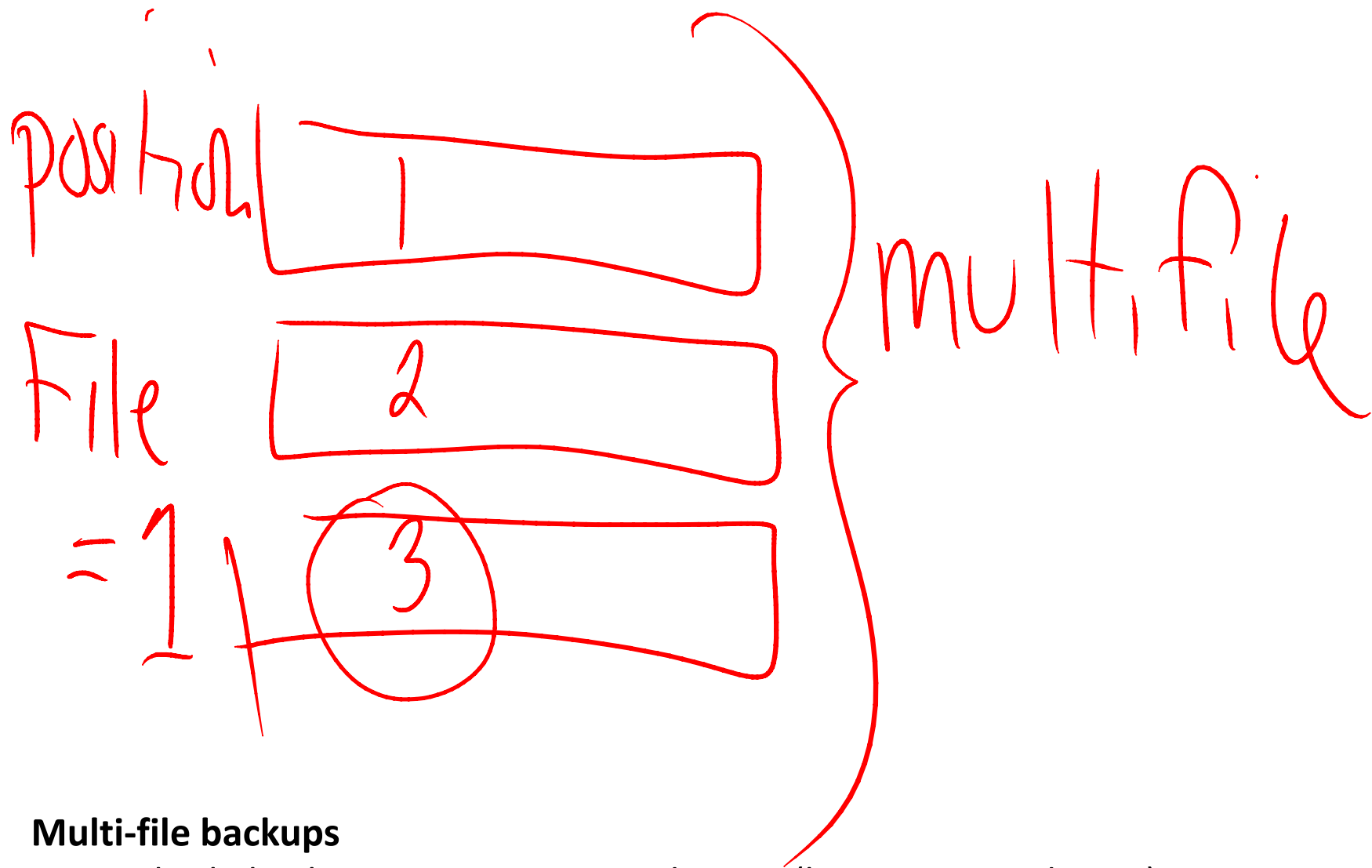
Disadvantages:

- No STOPAT
- Data loss possible if media failure...
- If database becomes suspect, cannot back up tail of log.



Best Place for Bulk_Logged

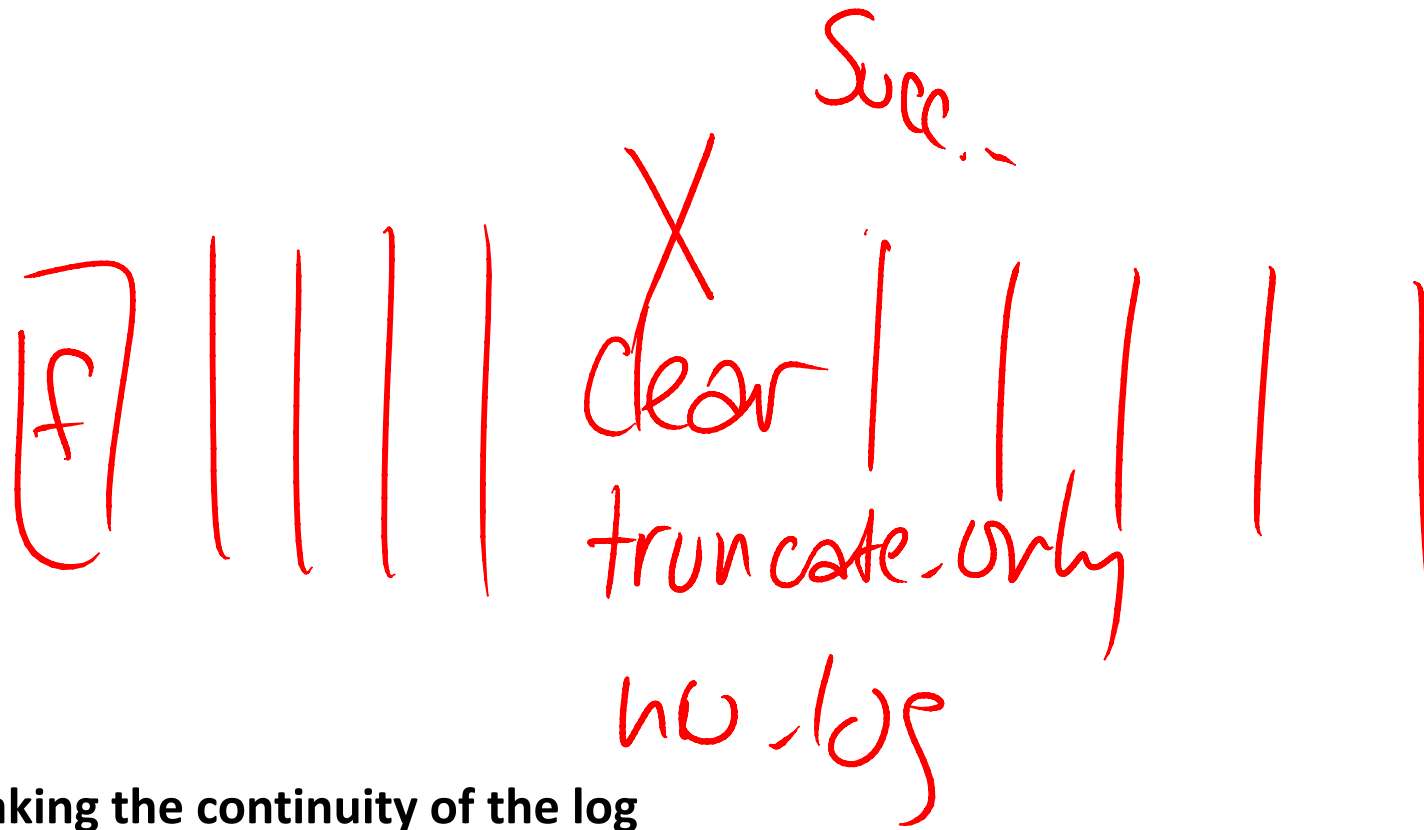
While you're in the bulk_logged recovery model (and IFF a bulk_logged operation as occurred) you can backup the log – as long as the data portion is available. If the data portion becomes damaged then up to the minute recovery will not be possible. It's very important to control when the db is in bulk_logged because even a table creator could put you into a minimally logged mode when you don't expect it (if you just always run in bulk_logged). See the prior slide for the best way to set/change recovery models from bull to bulk_logged and back.



Multi-file backups

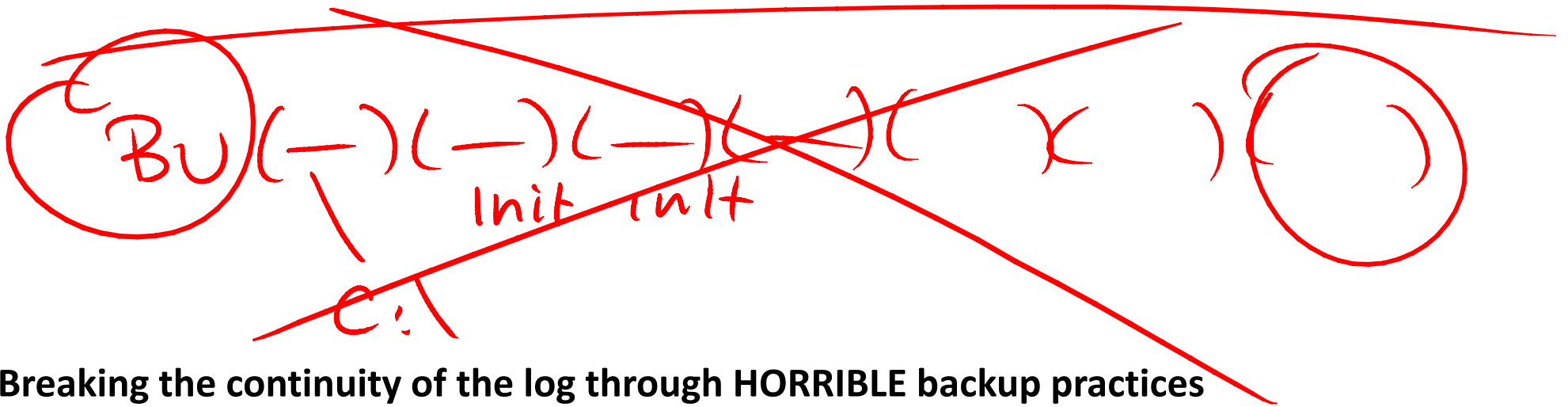
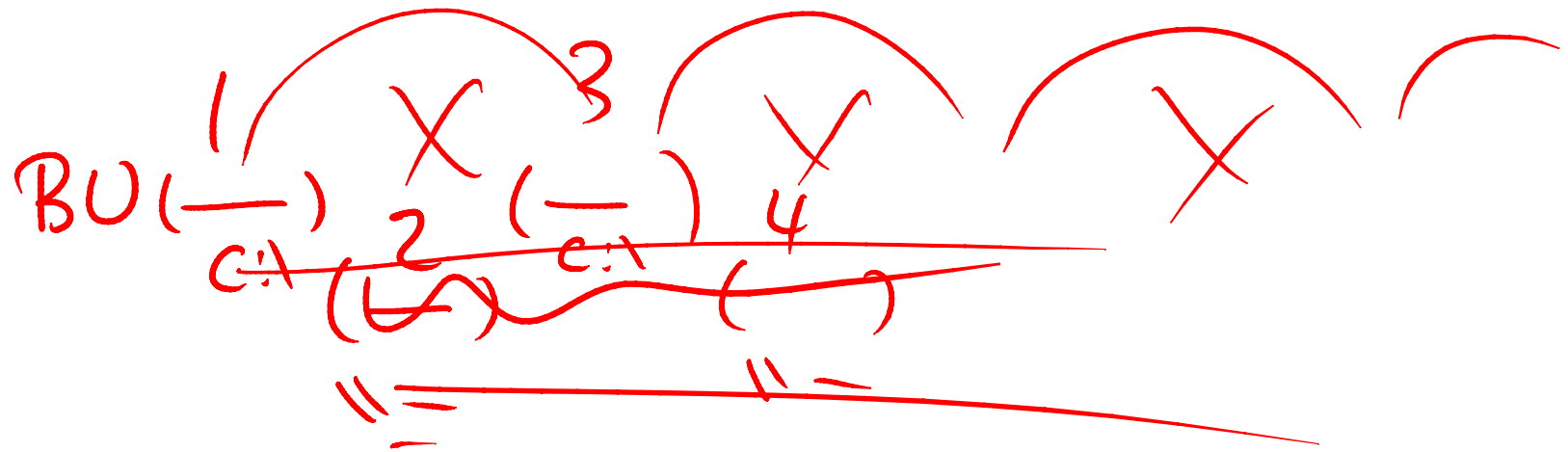
Are multiple backups to one or more devices (known as a media set). Once a media set has been defined, all backups to that media set must match in number as well as compression setting. If you want to change compression or use a different number of backup devices – you must use the WITH FORMAT option. When specified the media set is overwritten and any remaining “fragments” are completely and totally unusable.

2000



Breaking the continuity of the log

In SQL Server 2000, you can continue to successfully perform log backups even after the continuity of the log has been broken (YIKES!). To stop this possibility of this happening when someone uses `BACKUP LOG WITH TRUNCATE_ONLY` or `NO_LOG`, use trace flag 3231 (see the slides for more details). These commands are turned into a NOOP (null operation) in SQL Server 2000 and 2005 with 3231. On SQL Server 2005, 3230 turns them into a CHECKPOINT (which has no [negative] effect on databases in the FULL or BULK_LOGGED recovery models).

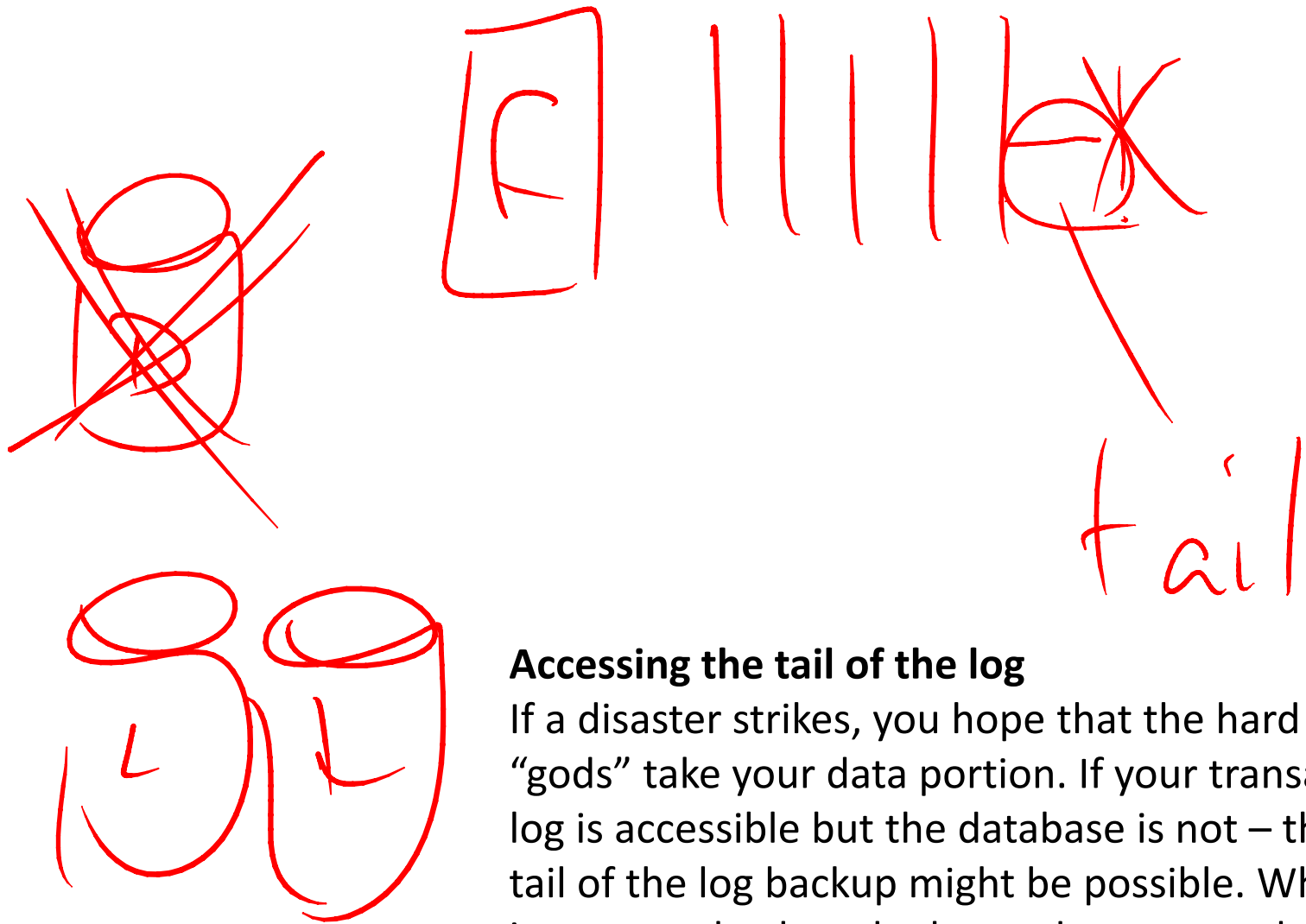


Breaking the continuity of the log through HORRIBLE backup practices

The first “strategy” was one that Edward had experienced. His customer had been backing up every OTHER backup to the network. So, local then network, then local, then network. This is a recipe for disaster!

The second “strategy” is one where the customer did NOT understand log backups AT ALL. They were backing up every log with INIT. If they had had a disaster they would have had the backup plus ONLY the last few transactions with NO WAY of getting the log to a useable point.

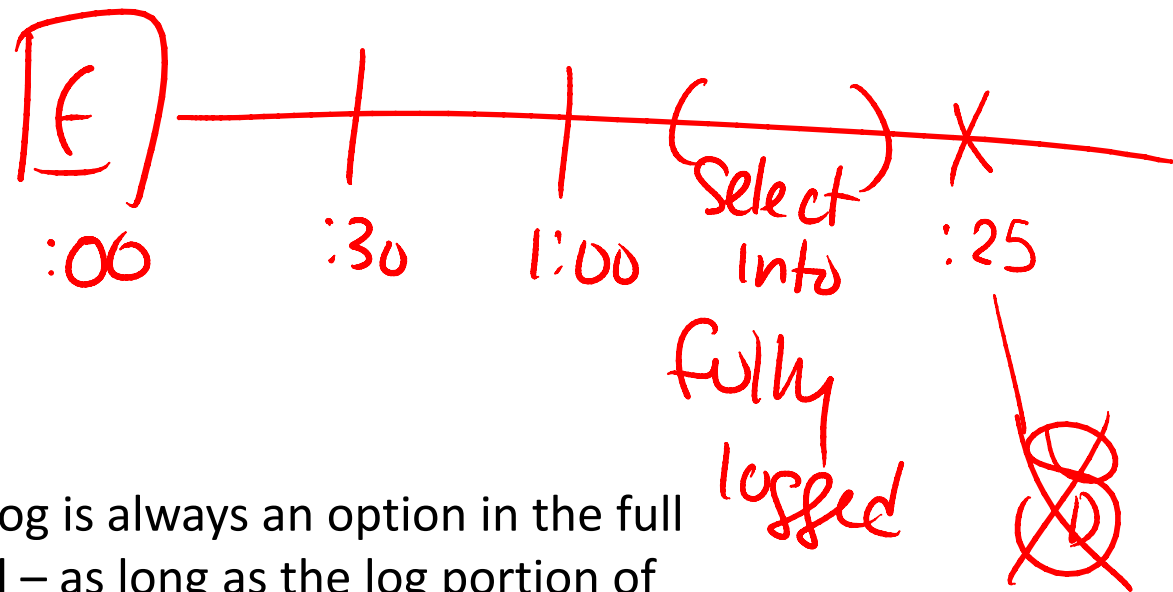
Key Point: TEST YOUR BACKUP/RESTORE STRATEGY



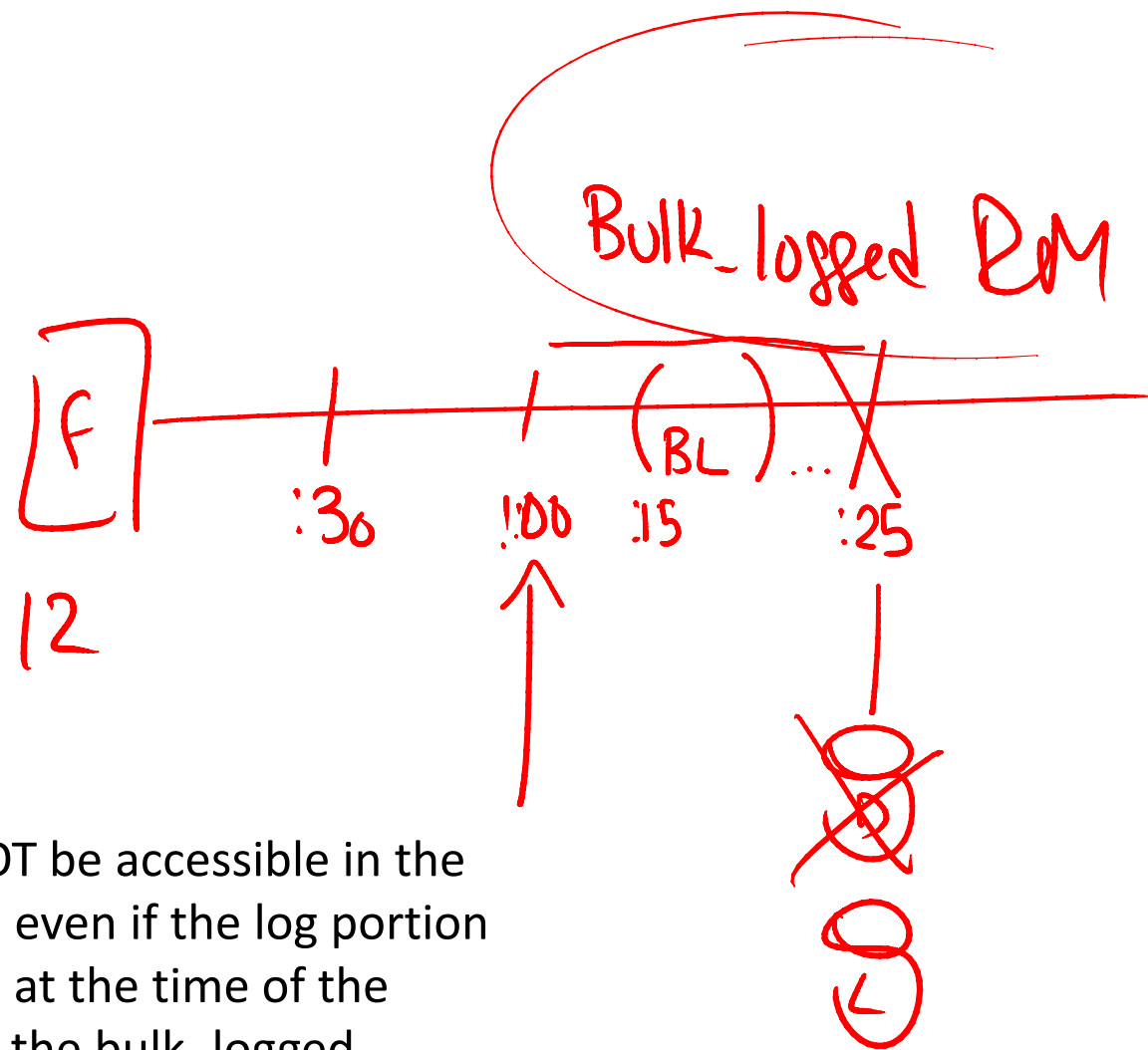
Accessing the tail of the log

If a disaster strikes, you hope that the hard drive “gods” take your data portion. If your transaction log is accessible but the database is not – then a tail of the log backup might be possible. When it is, you can backup the log and get up-to-the-minute recovery of your database (with ZERO data loss). This is why redundancy for the log is the most important – even more so than for the data portion. However, you need redundancy there as well to minimize downtime.

Full RM



The tail of the log is always an option in the full recovery model – as long as the log portion of the database is accessible at the time of the disaster. If the database is in the FULL recovery model then ALL operations are fully logged (even those that have the ability to be minimally logged; they are ONLY minimally logged if the database recovery model is NOT FULL).

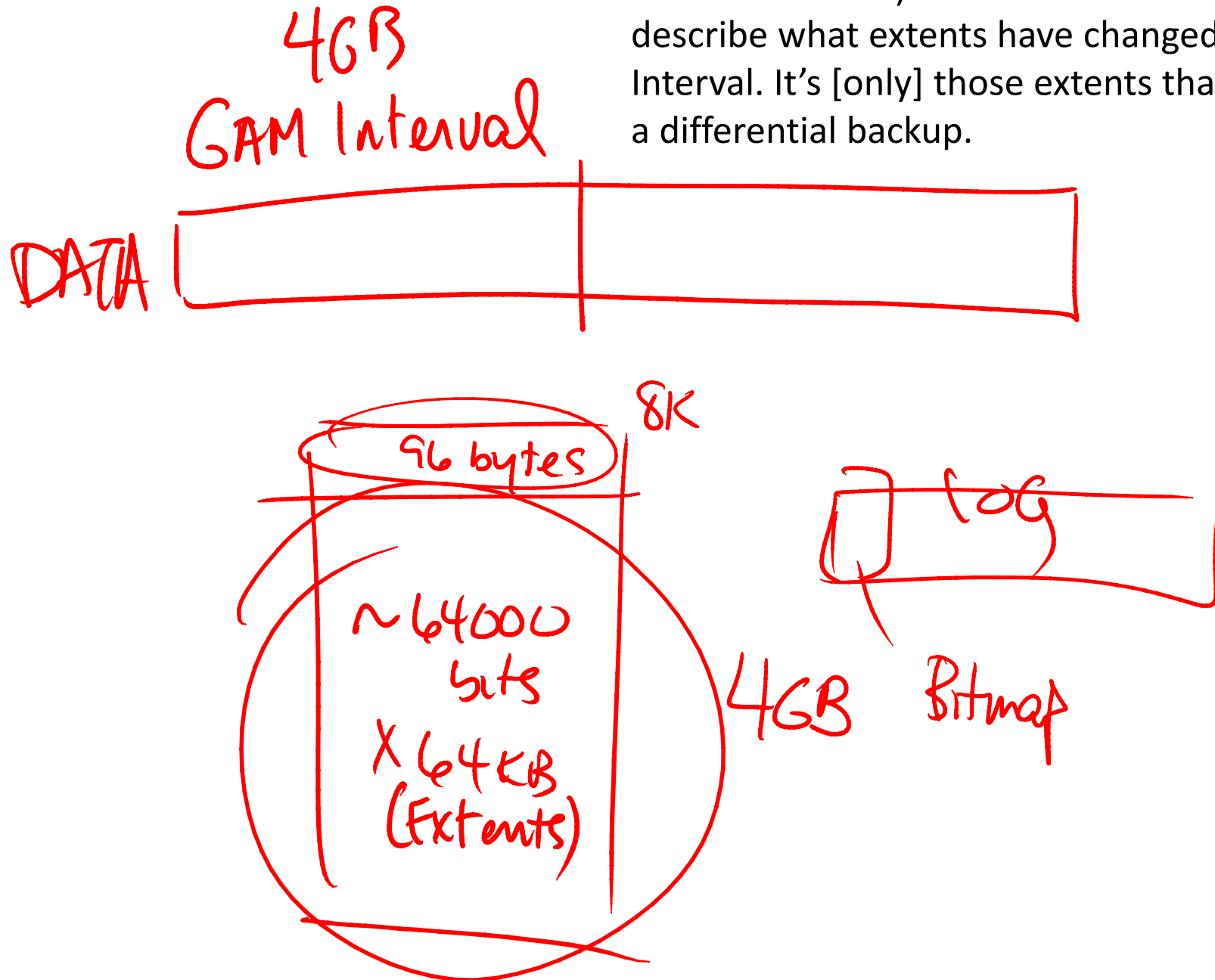


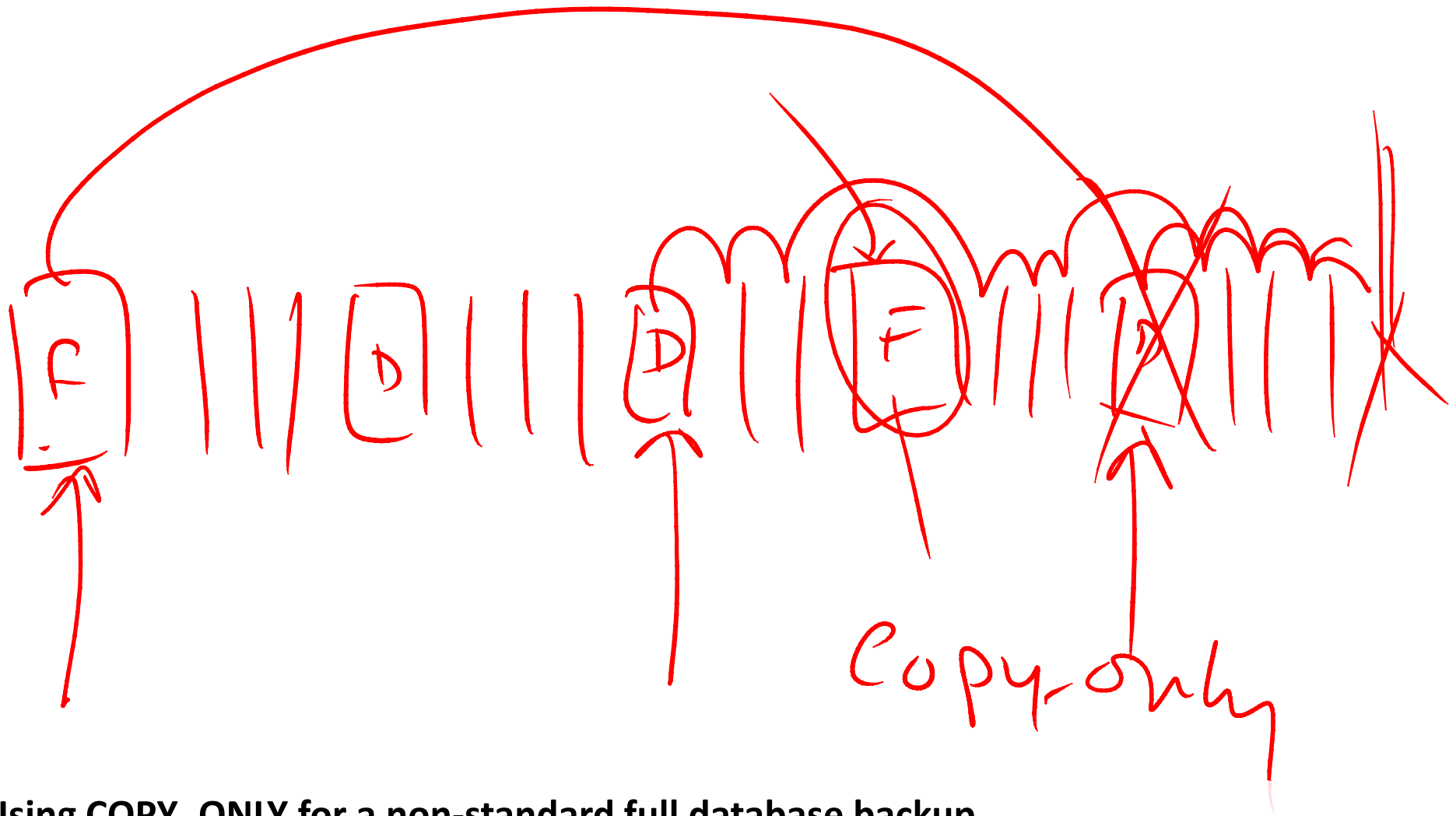
The tail of the log MIGHT NOT be accessible in the bulk_logged recovery model even if the log portion of the database is accessible at the time of the disaster. If the database is in the bulk_logged recovery model AND a bulk operation HAS occurred then the tail of the log cannot be backed up.

End result – be sure to protect the log by restricting the time that a database is in the bulk_logged recovery model and do not allow users into the database during this time.

IE1 Internals Review

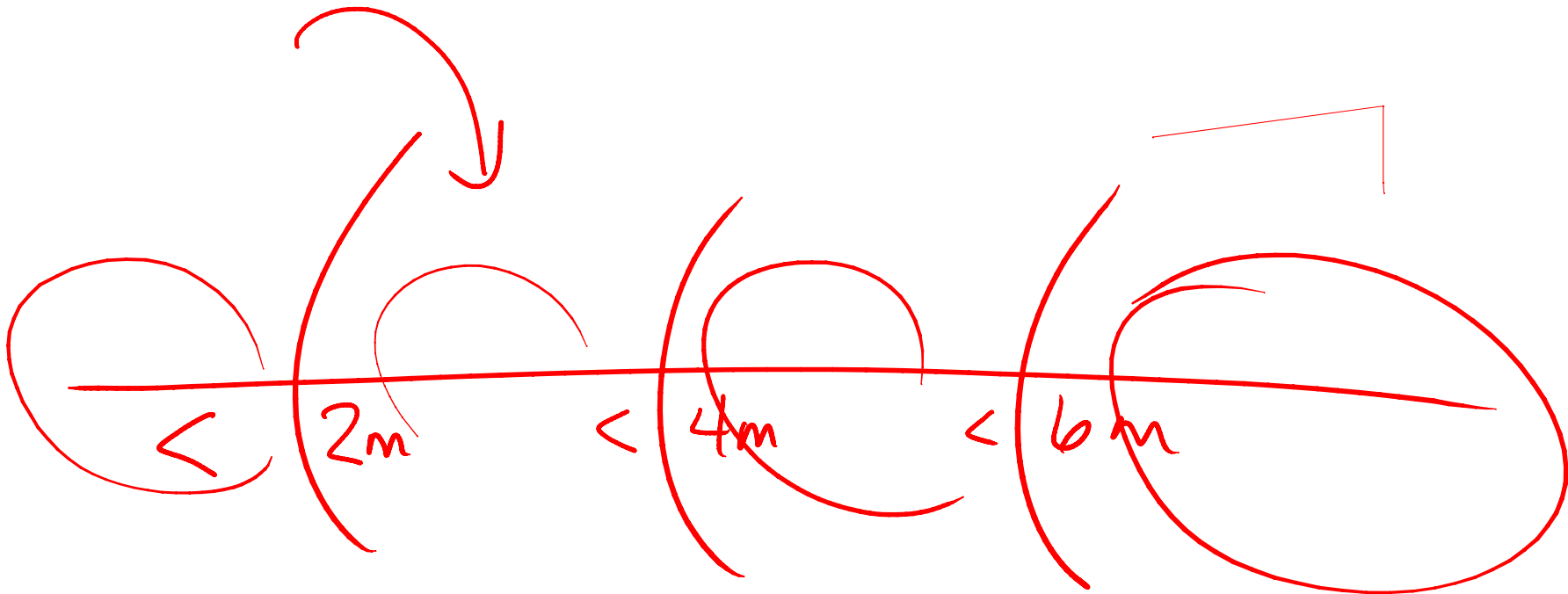
“Bitmap” pages in SQL Server use the 8K page as a map to describe *something* about a GAM Interval (4GB chunk of the file). A differential bitmap uses a page to describe what extents have changed within that GAM Interval. It’s [only] those extents that are backed up on a differential backup.





Using COPY_ONLY for a non-standard full database backup

If a developer/tester or another team needs a backup of a database, you do not just want to back it up and give it to them. Performing a full database backup resets the differential bitmap. All differentials would then be tied to that most recent backup and not the one that was performed during your regularly scheduled backups. As a result, your restore process might take quite a bit longer (and require quite a few more log backups to be applied). Use COPY_ONLY instead and the diff bitmap will not get reset!



Online operations – SalesDB partitioning

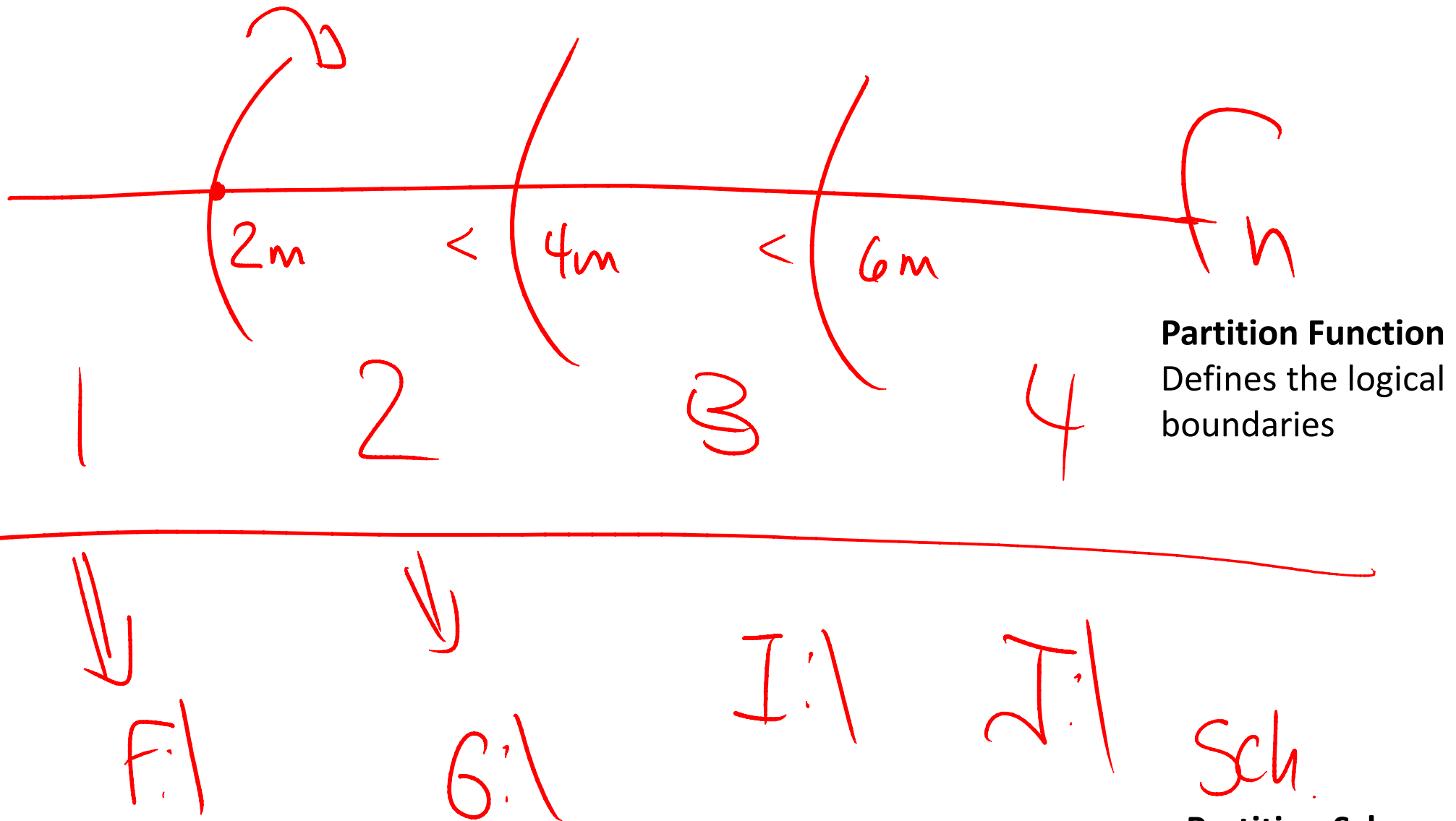
The sales table was partitioned with 3 boundary points: 2 million, 4 million and 6 million. It's a RIGHT-based partition function so the rows that match the boundary point will be to the RIGHT side. Specifically this translates into:

In partition 1: all rows less than 2 million

In partition 2: all rows equal to or greater than 2 million and less than 4 million

In partition 3: all rows equal to or greater than 4 million and less than 6 million

In partition 4: all rows equal to or greater than 6 million



Online operations – SalesDB partitioning

When I partitioned the sales data, I ended up writing the data to the USB drives.

Drive F:\ (partition 1): all rows less than 2 million

Drive F:\ (partition 1): all rows equal to or greater than 2 million and less than 4 million

Drive F:\ (partition 1): all rows equal to or greater than 4 million and less than 6 million

Drive F:\ (partition 1): all rows equal to or greater than 6 million

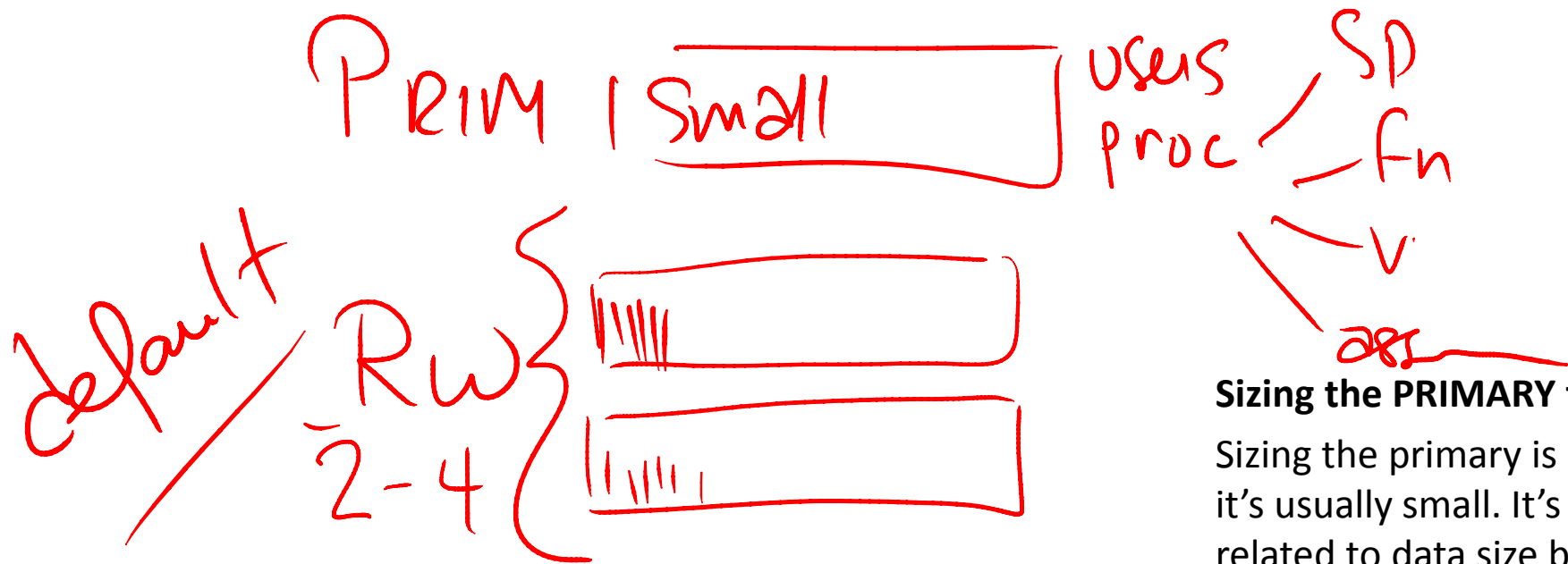
Partition Scheme

Defines the physical location for the data



Primary filegroup, Primary file?

The first file associated with a database is the MDF (main data file) which is also known as the PRIMARY DATA FILE (but Adobe beat us to PDF 😊). This file is critical for a database to be up and running. If you add files to a database without specifying a filegroup they are going to end up in the PRIMARY filegroup. Because the primary file is a member and because allocations can come from any file of the filegroup – ALL of the files of the primary filegroup end up being critical. Generally, it's important to isolate the primary filegroup (with just one mdf) and protect it (as much as you would the transaction log).



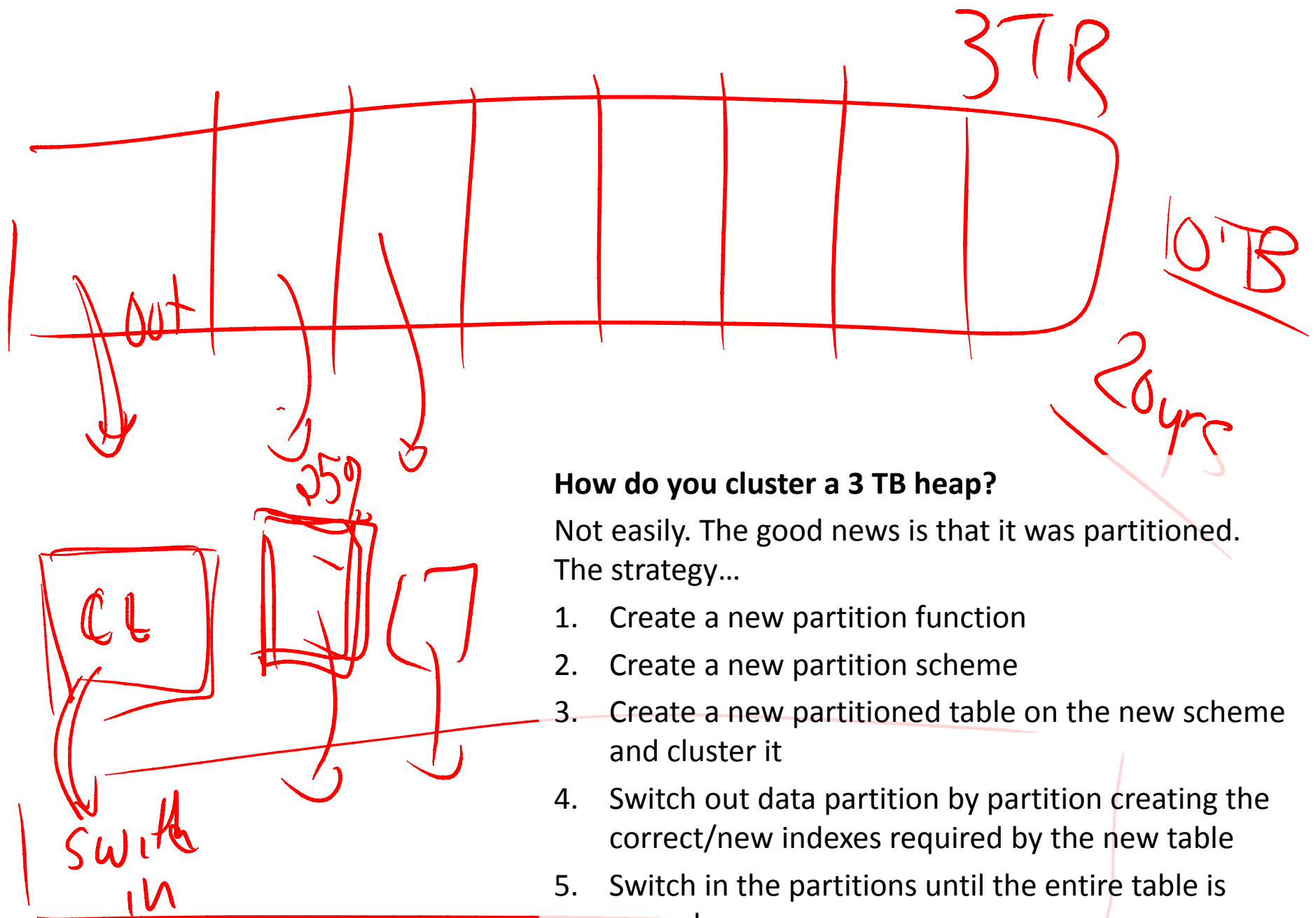
Sizing the PRIMARY filegroup

Sizing the primary is challenging but it's usually small. It's not directly related to data size but instead related to metadata complexity. Users/permissions as well as code (functions, procedures, assemblies) are what's stored in the "primary" portion of the database.

RO 2011 → R10
RO 2010 → R5
RO 2009 → R0

Isolating the primary filegroup

More specifically, isolate primary and separate this from your user-defined data. Create a filegroup for readwrite data that has at least 2 files and then read-only data can be in one or more filegroups (depending on availability requirements, backup/restore SLAs and hardware options/costs)



How do you cluster a 3 TB heap?

Not easily. The good news is that it was partitioned.
The strategy...

1. Create a new partition function
2. Create a new partition scheme
3. Create a new partitioned table on the new scheme and cluster it
4. Switch out data partition by partition creating the correct/new indexes required by the new table
5. Switch in the partitions until the entire table is moved over

Concerns:

- * primary/foreign keys
- * downtime

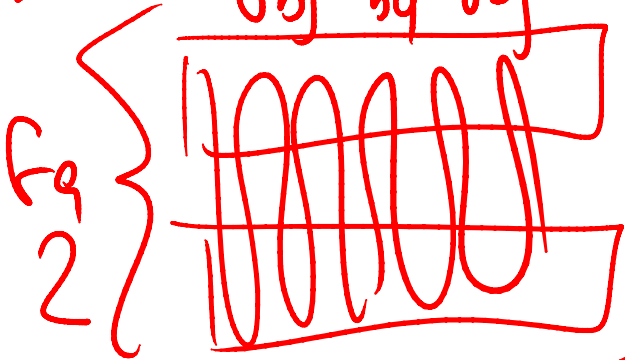
fg



Removing does
balance

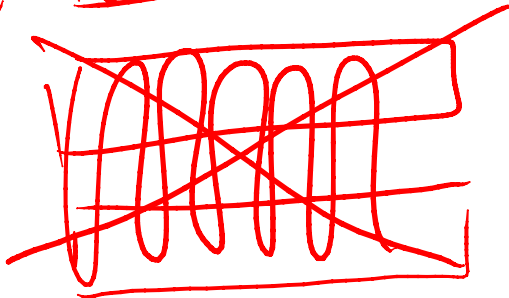
Remove Empty file

Obj by obj



New
fg
4

rebuild in



not
ADD

**Changing the
number of files in
a filegroup**

See the next slide
for details.

Changing the number of files in a filegroup

Removing a file must be done through EMPTYFILE (which DOES rebalance the data among the remaining files in the filegroup). However, it is not object specific.

Adding a file to a filegroup does NOT rebalance. If you want to change a filegroup from two or three files to something like four or five, your best bet is to create a NEW filegroup and then rebuild all of your indexes into it.

Use CREATE with DROP_EXISTING to MOVE an index to another filegroup.

Now, as for moving LOB data... this is the most interesting and it DOES work if you use DROP_EXISTING and rebuild on a scheme or conversely from a scheme to just a single filegroup. However, going from one filegroup to another (even when using DROP_EXISTING) does NOT move the LOB data. There's a blog post in that information for sure. I might try and do this as a SQLServerPro post in my series on Partitioning (Partitioned Tables vs. Partitioned Views).

Here are the links to the current posts:

Q1: [Partitioned Tables v. Partitioned Views—Why are they even still around?](#)

Q2: [Solutions to VLT concerns around statistics and maintenance!](#)

Q3: [Did SQL Server eliminate any partitions?](#)

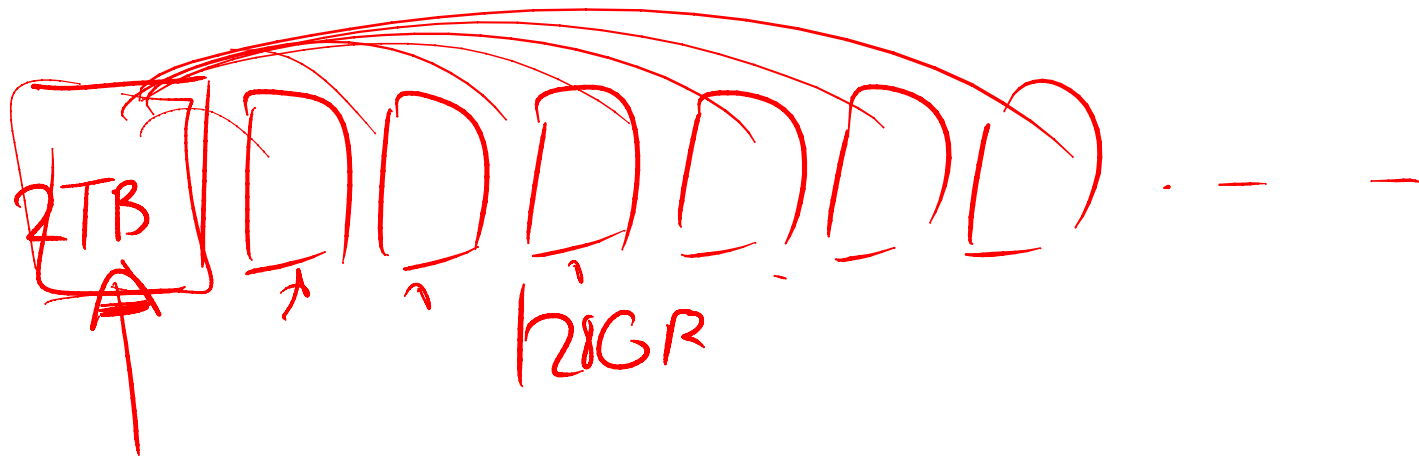
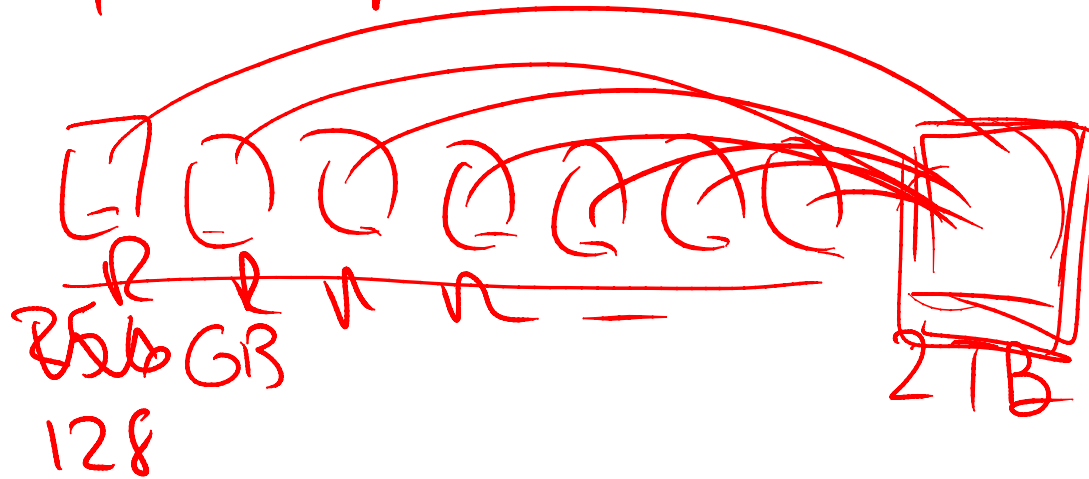
Q4: [How about Filtered Indexes instead of Partitioning?](#)

Q5: Is there a way to move LOB data? (or something like that)

The final consideration is availability. See the next slide for Brad's (@SQLPhilosopher's) trick!



SQL philosopher.com



As an alternative, Brad (@SQLPhilosopher) came up with a way to move LOB data to a different number of files – and, do this as an ONLINE operation.

He described it fully here: <http://www.sqlphilosopher.com/wp/2012/02/moving-a-filegroup-to-a-new-disk-array-with-no-downtime/>.

It's not a different filegroup but the end result (restructuring the filegroup) is the same!

SQLskills Immersion Event

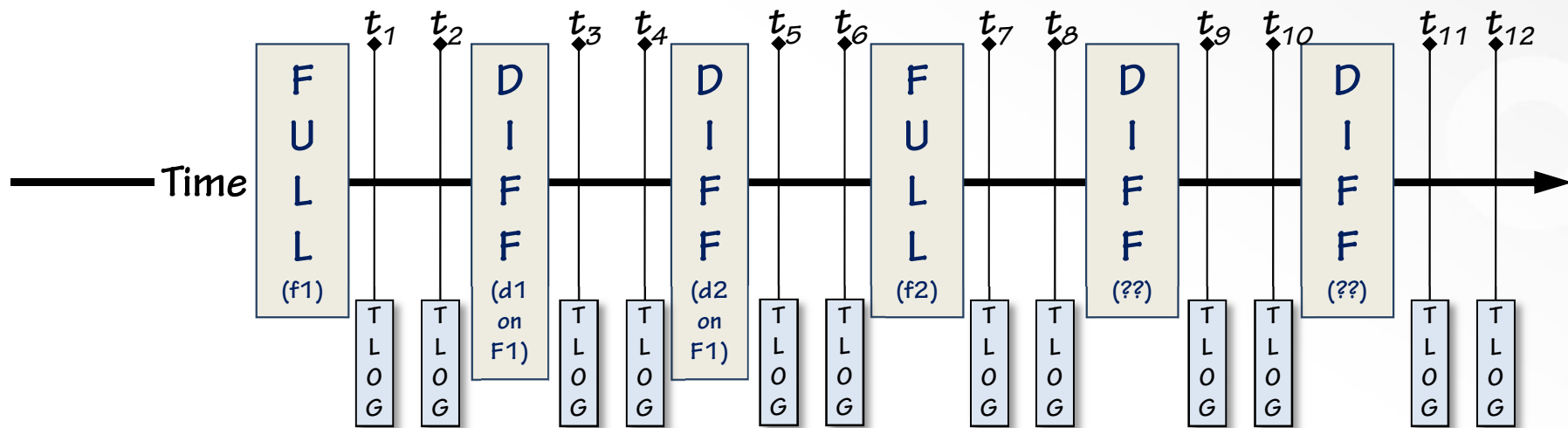
IE3: High Availability & Disaster Recovery

Module 4: Restore Internals and Procedures

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Kimberly@SQLskills.com

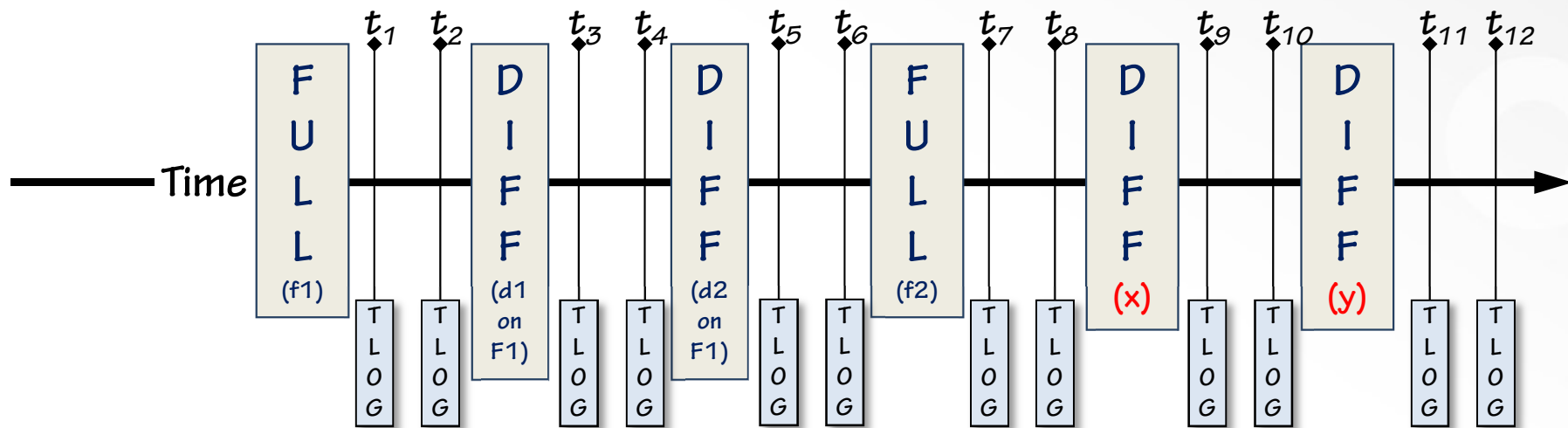


Differential Chain with/without COPY_ONLY

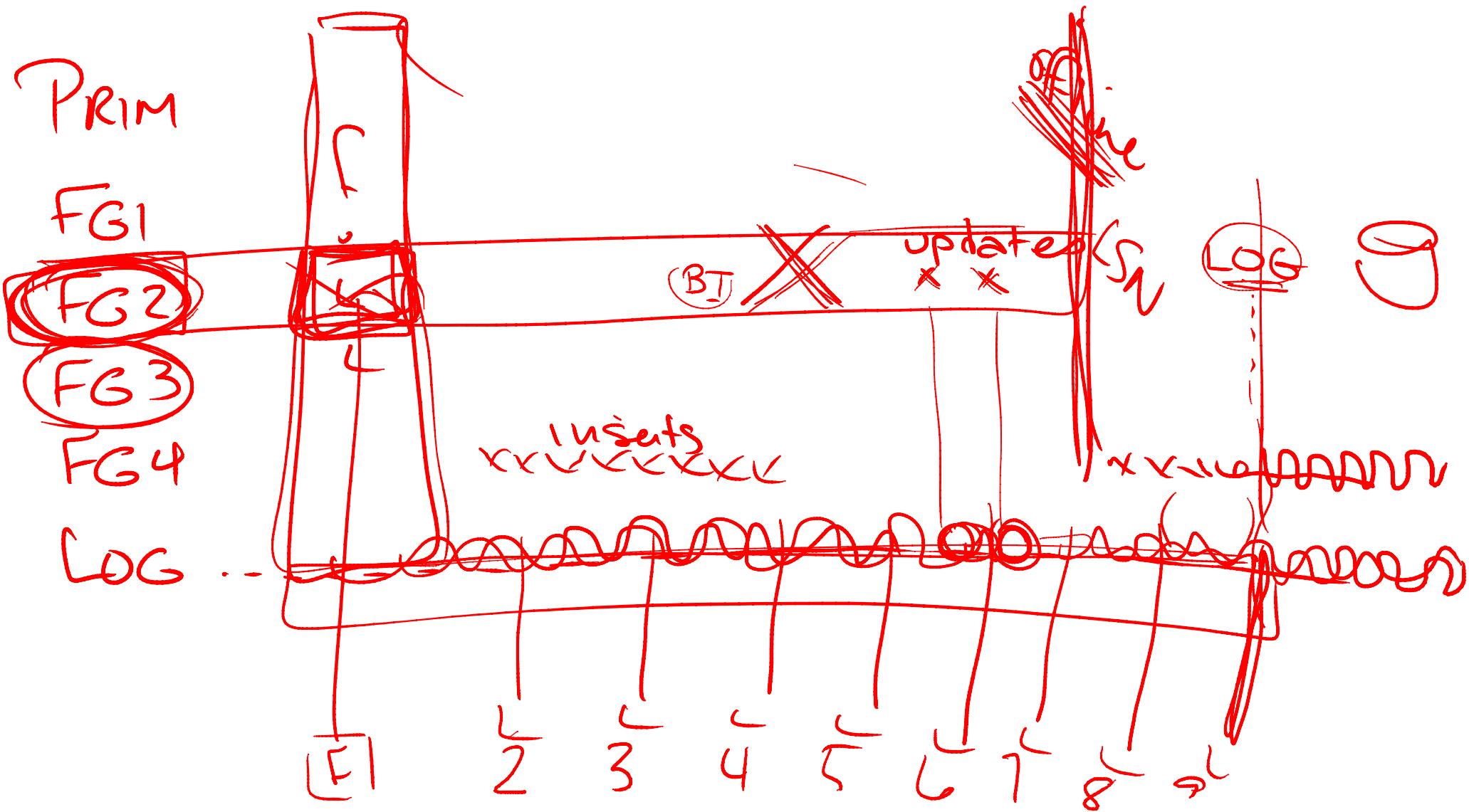


- If the full database backup at f2 is performed without using COPY_ONLY) then
 - The differentials that follow cannot be used with full database backup performed at f1
 - The differential bitmap is reset at f2
- If the full database backup at f2 is performed using COPY_ONLY, then
 - The differentials that follow CAN be used with full database backup performed at f1
 - The differential bitmap is not reset at f2

Recovery Sequence with/without COPY_ONLY

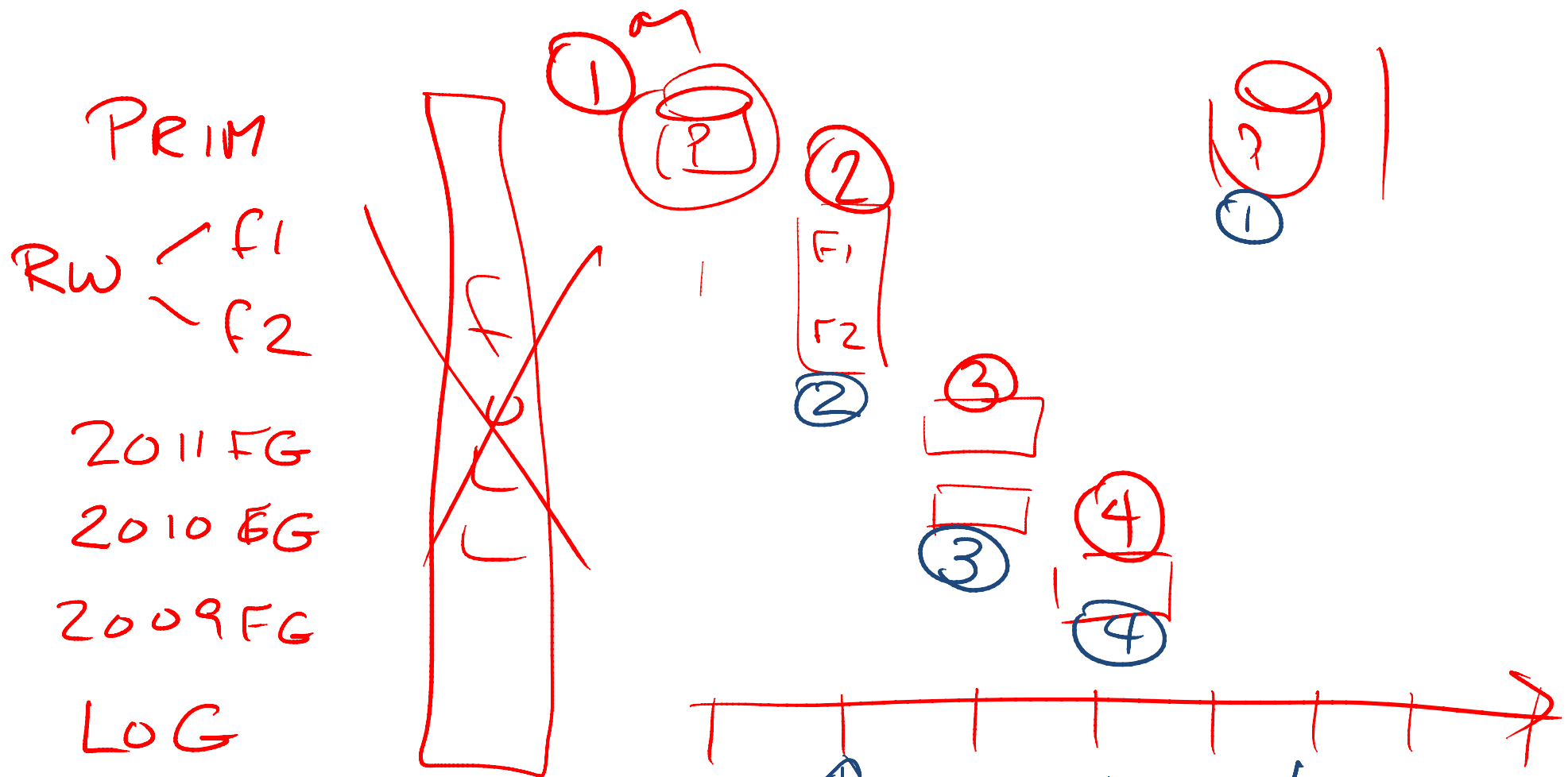


- If the full database backup at f2 is performed without using COPY_ONLY) then
 - Recover the full at f2 then the diff at **y** then t_{11} and t_{12}
 - What if the backup at f2 was deleted/thrown away?
 - Recover the full at f1 then the diff at **d2** then all of the tlogs t_5 through t_{12}
- If the full database backup at f2 is performed using COPY_ONLY, then
 - Recover the full at f1 then the diff at **y** then t_{11} and t_{12}



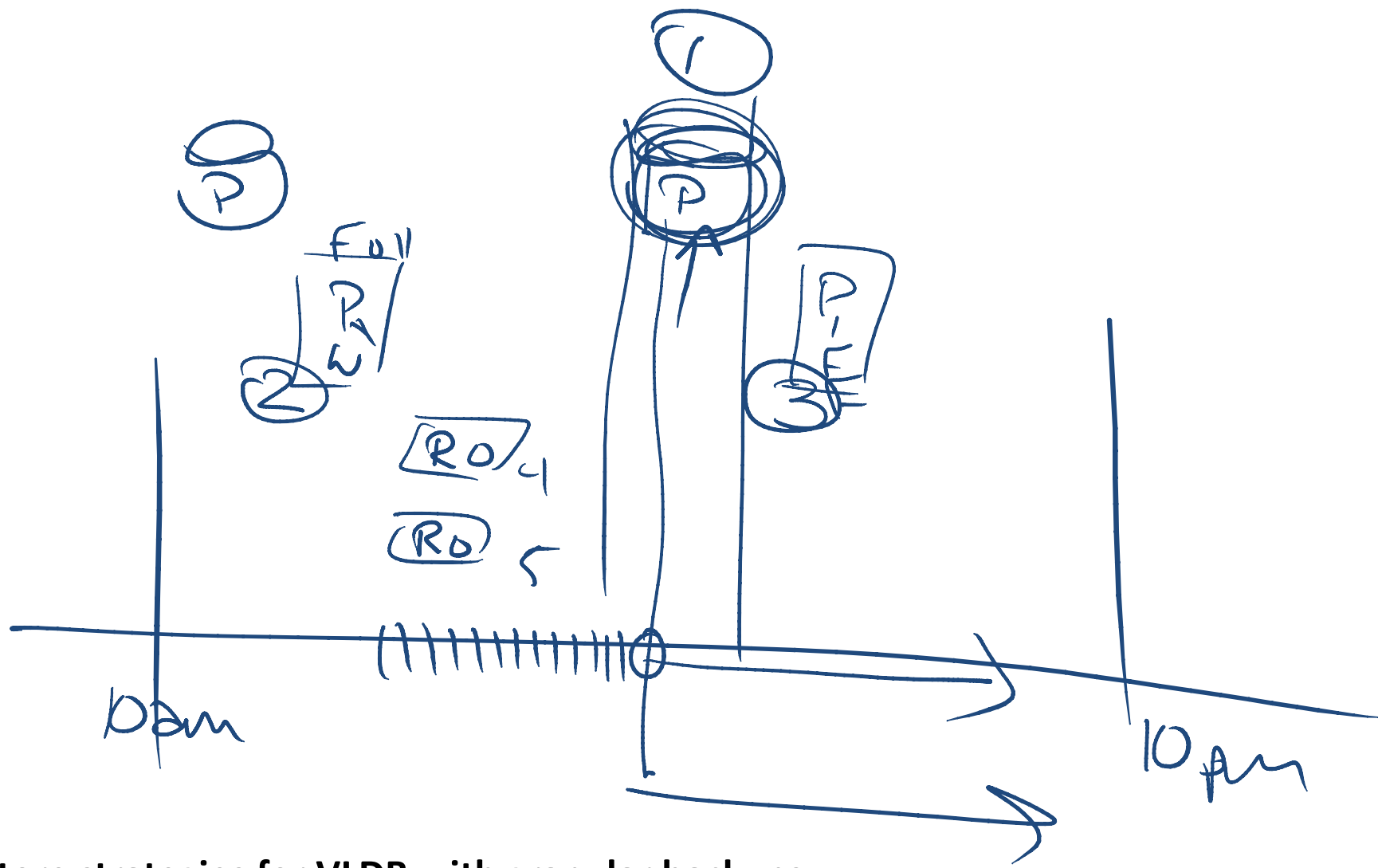
Taking a filegroup OFFLINE

This shows a multi-file database and a series of different types of backups. What was most important here is the understanding of what happens when a filegroup is taken OFFLINE. This is the point in time when SQL Server knows that no new transactions will occur. This is the point in time to which this filegroup must be restored (reconciled) in order for this filegroup to be brought online.



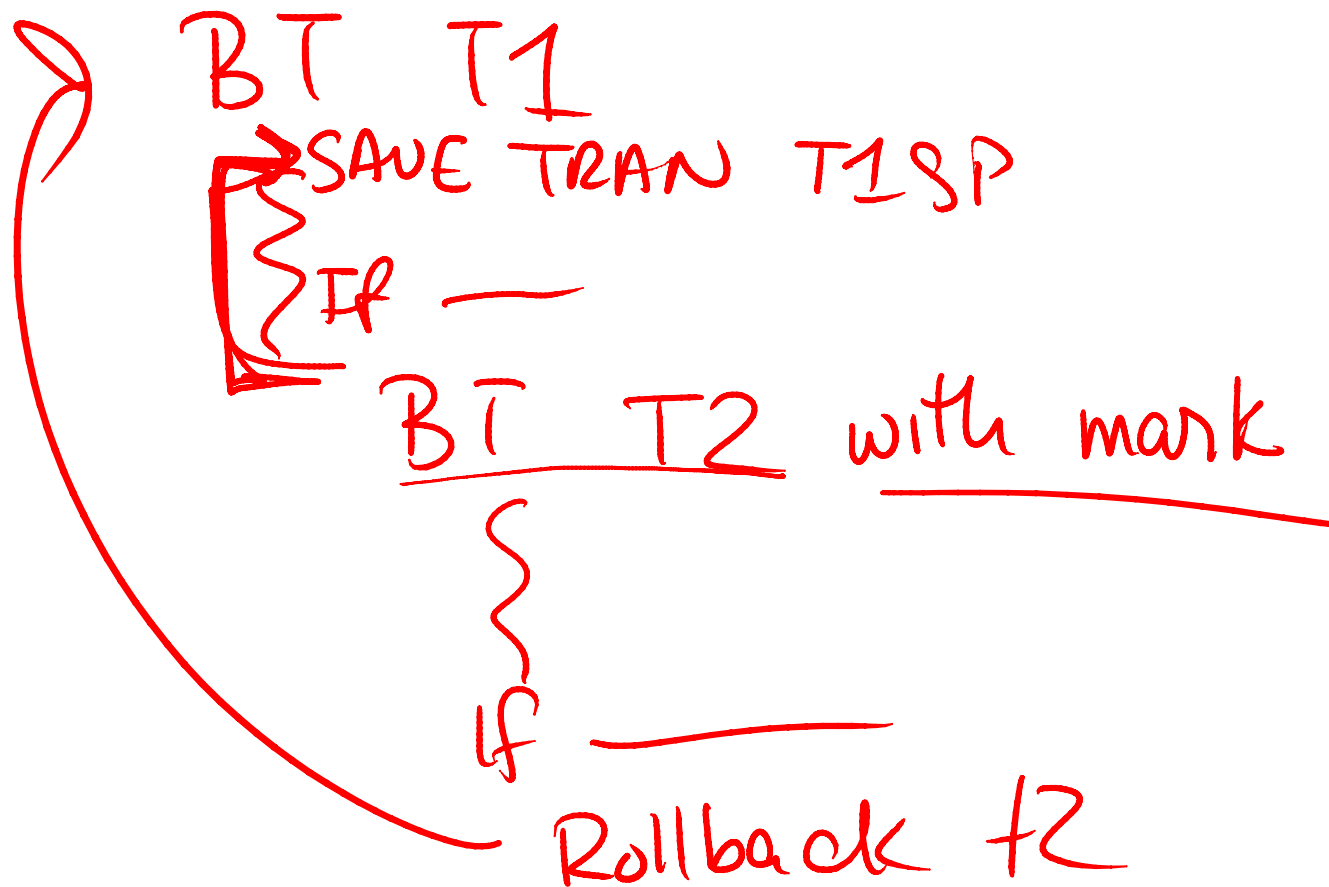
Restore strategies for VLDDB with granular backups

To reconstruct a database from granular backups requires that ALL pieces are restored. However, since they were backed up at different times – a transaction log series that starts with the oldest filegroups minimum (or effective) LSN must be used. If you have a current primary and all of the filegroups (labeled in blue as 2, 3, 4) then you only need logs starting with the bottom blue arrow. If the blue backup #1 did not exist and you had to go back to the red #1 then you'd need all of the logs back to that point. The KEY point is that the database will be completely offline until the entire set of filegroups being restored are recovered to the SAME point in time. If you restore PARTIAL then you could bring it online more slowly/granularly.



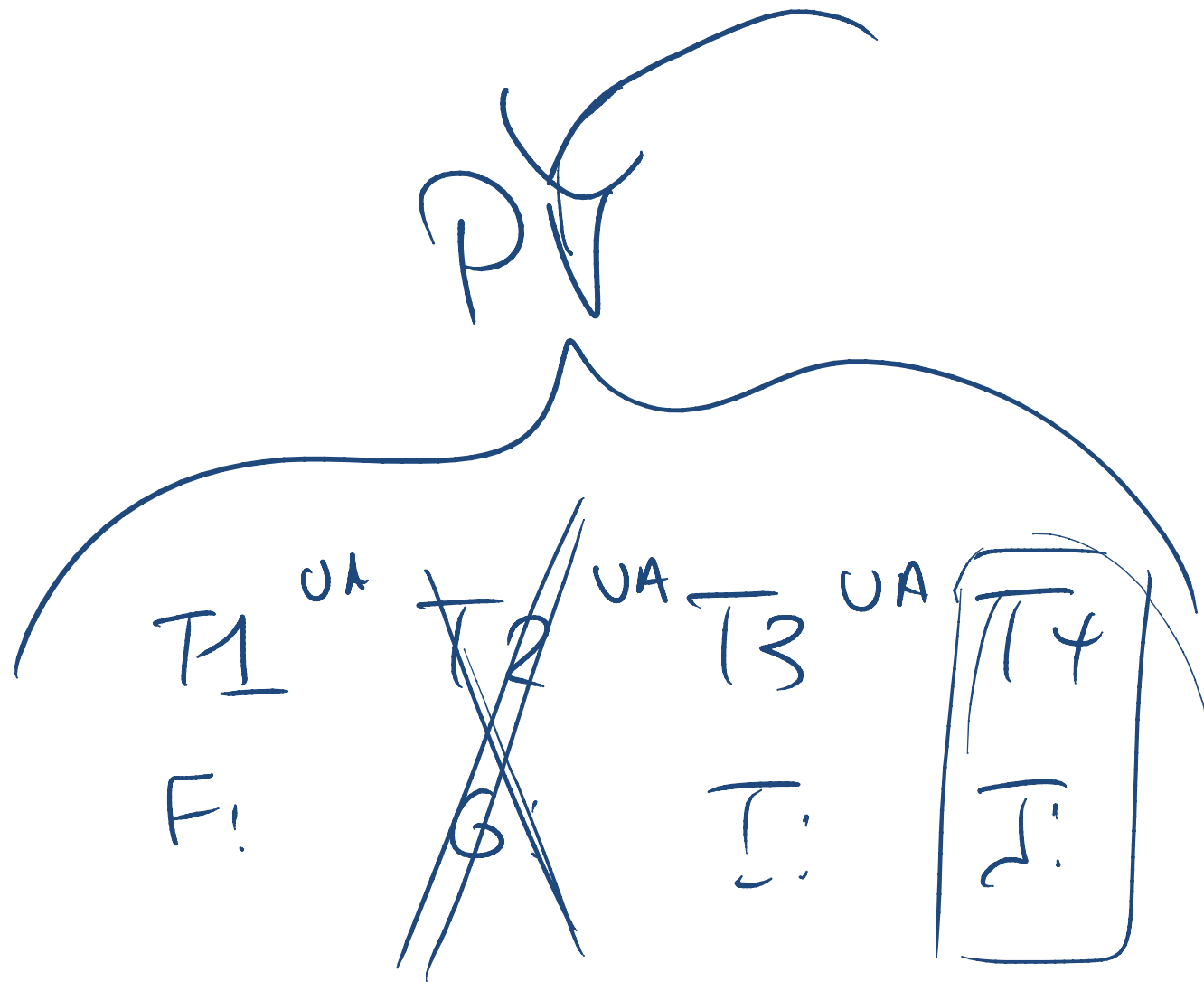
Restore strategies for VLDB with granular backups

This is a continuation of the last picture. If you have a primary filegroup backup (#1) then a RWFilegroup backup (#2) then you could restore that with logs to bring the entire database up to current (restoring the RO filegroups at virtually any time – possibly a lot later if you really just want to get the RW up to current). If you have a differential of the RWFilegroup then you could have restored it and then you only would have needed the logs from the backup time of the Primary filegroup.



Restore with STOPATMARK (or STOPBEFOREMARK)

A marked transaction has very few uses. You CANNOT rollback to a mark (remember, a transaction is always a SINGLE unit of work) and so what use do they serve? If they're nested – really none. However, if you do complete a marked transaction then you can use that as a restore point during recovery. Stop at mark – stops at and includes the completed/marked transaction and stop before mark – stops with all committed transactions prior to the mark.



Querying data when a filegroup is damaged

If you query a partitioned table when a filegroup is damaged then you'll only receive an error if you (try to) select from the damaged partition. This is also NOW true of a partitioned view. It was not always true (in 2005 a view that was damaged would fail). This was fixed in 2008+



The concept is this... if a database uses column-level encryption and therefore stores encrypted data, then you'll need to re-associate the DMK (database master key) with the new server's SMK (service master key) when you restore. Otherwise, all of the data will be inaccessible!

```
USE database;
```

```
go
```

```
-- Open the DMK with the SAME password used when created:
```

```
OPEN MASTER KEY DECRYPTION BY PASSWORD = 'original password';
```

```
go
```

```
-- Reassociate the DMK with the SMK of the new instance:
```

```
ALTER MASTER KEY ADD ENCRYPTION BY SERVICE MASTER KEY;
```

```
go
```

Encryption Hierarchy

- SQL Server 2005+ implements a framework to help protect encryption keys by using an encryption key hierarchy, as shown in the figure on this slide. In this hierarchy, each layer encrypts the layers that are below it.
- The Data Protection API (DPAPI) is at the top of this encryption key hierarchy. DPAPI is a pair of function calls that provide operating system–level data protection services to user and system processes. Because this API is part of the Microsoft Windows® operating system, applications can use DPAPI to encrypt data but do not have to use any cryptographic code other than the code that calls the DPAPI functions. DPAPI is a password-based data protection service. Therefore, DPAPI requires a password to encrypt the data.
- The SQL Server 2005 Service Master Key is a symmetric key that the **cryptGenKey** function automatically generates when an administrator installs SQL Server 2005. DPAPI uses the password of the account under which SQL Server 2005 runs to generate a key with which DPAPI encrypts the Service Master Key. Therefore, if an administrator changes the service account under which SQL Server 2005 runs, he or she must decrypt the Service Master Key by using the original credentials. Then, he or she must encrypt the Service Master Key by using the new credentials. We strongly recommend that administrators change the service account under which SQL Server 2005 runs only by using the SQL Server 2005 Computer Manager tool. This tool automatically performs the required steps to decrypt the Service Master Key, and to then re-encrypt the Service Master Key.
- The Service Master Key encrypts the Database Master Key. The Database Master Key is required in each database where an organization encrypts data. This key provides the same functionality as the Service Master Key. However, the functionality occurs at a database level instead of a SQL Server 2005 instance level.
- The Database Master Key is a symmetric key. It is not automatically created when a new SQL Server 2005 database is created. Therefore, the developer must explicitly create this key to implement encryption in a database.
- The Database Master Key encrypts the user keys that a developer creates. These user keys include certificates and asymmetric keys. In turn, certificates and asymmetric keys encrypt symmetric keys that the developer creates.
- **Note:** A developer can also use certificates and asymmetric keys to encrypt data directly. However, certificates and asymmetric keys are best suited to encrypt only small amounts of data.
- A developer can use symmetric keys to encrypt other symmetric keys that he or she creates or to encrypt data. This encryption key hierarchy is especially important to consider when the developer determines the type of key to use to encrypt newly created keys. The SQL Server 2005 encryption key framework gives a developer a large amount of flexibility to create a simple or complex encryption key hierarchy for each database that he or she creates. However, we recommend that a developer create as simple a key structure as his or her organization allows.

Encryption Hierarchy

