



A detailed look at the
on-disk structure of the
VMS Advanced File
System (VAFS)

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History of VAFS

- Started by DEC engineers in Edinburgh, Scotland in 1996
 - They previously did Spiralog
- Designed to run on multiple operating systems (VMS, Windows NT)
- Moved to VMS Engineering (Nashua, NH) in 1998
- Developed on and off until 2004
- Restarted by VSI in 2016

Need for a new file system

- Volume size limited to 2TB
- Performance
- Number of files on disk and in a directory is limited

ODS-2/5 Limitations

- 32 bit VBN & LBN
- 512 byte block dependency
- Sequential directory format
 - Square law delete performance
- “Careful write” update strategy
 - Deferred write requires a log for safety
- Bitmap based allocation
 - Linear solution to an exponential problem
- Code entropy

Storage Scale

- 32 bit LBN = 2TB
- >2TB hard drives have been available for a while
- >2TB logical volumes have been possible for a long time
- **Any** solution requires an on disk structure change

Storage Scale – Market Demands (2004)

- Mormon church genealogical database
 - Projected 50PB several years ago
- Medical imaging
 - 1 digitized X-ray = 1GB
 - 1 CAT scan = 100-200GB
- Russian Customs
 - 120TB database, 1TB / week log file
 - Planned video archive requires 2PB

File System Performance

- Typical Unix file system is 10x faster than VMS for open/close/create/delete
- Deferred write (both user data & FS metadata)
- Write-ahead logging in current file systems
- Shorter code stack – no RMS/XQP layering
- Simpler file naming semantics (no logical names)
- No shared-everything cluster model
 - Distributed locking
 - Thrashing updates

Benefits of VAFS

Performance

Extensibility

Maintainability

Scalability

Benefits of VAFS

Performance

- Write behind caching
- Metadata writes to sequential log
 - “Metadata” being (in ODS-2/5 terms) INDEXF.SYS, *.DIR, QUOTA.SYS, ACLs

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Maintainability

- Small number of basic concepts used as building blocks (List Pages, Streams, Trees)
- Written in C (no MACRO, no BLISS)

Benefits of VAFS

Scalability

- Large disk support (64-bit LBNs)
- More files on volume
- More files in a directory
- Space allocation performance improvement
- Recovery time after crash (MOUNT /REBUILD)

VAFS vs. ODS-2/5: Similarities

DCL utilities (COPY, DELETE, EDIT, MOUNT, INIT, etc...)

User-visible interfaces and upper-layer data structures

- FCB's
- WCB's
- ACP-QIO Interface
- XFC
- ACL's
- Disk quotas
- File ID's
- RMS
- File sizes limited to 1TB (RMS 32-bit limitation)
- Host-Based Volume Shadowing

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- VAFS uses "disk pages" of 2048 bytes as unit of operation (may be increased to 4096)
- No volume sets, bad block handling, geometry sensitivity, placed allocation
- Cannot be a system disk on IA64 or Alpha (yes on X86)

A newly-initialized VAFS disk

Directory \$1\$DGA220:[0,0]

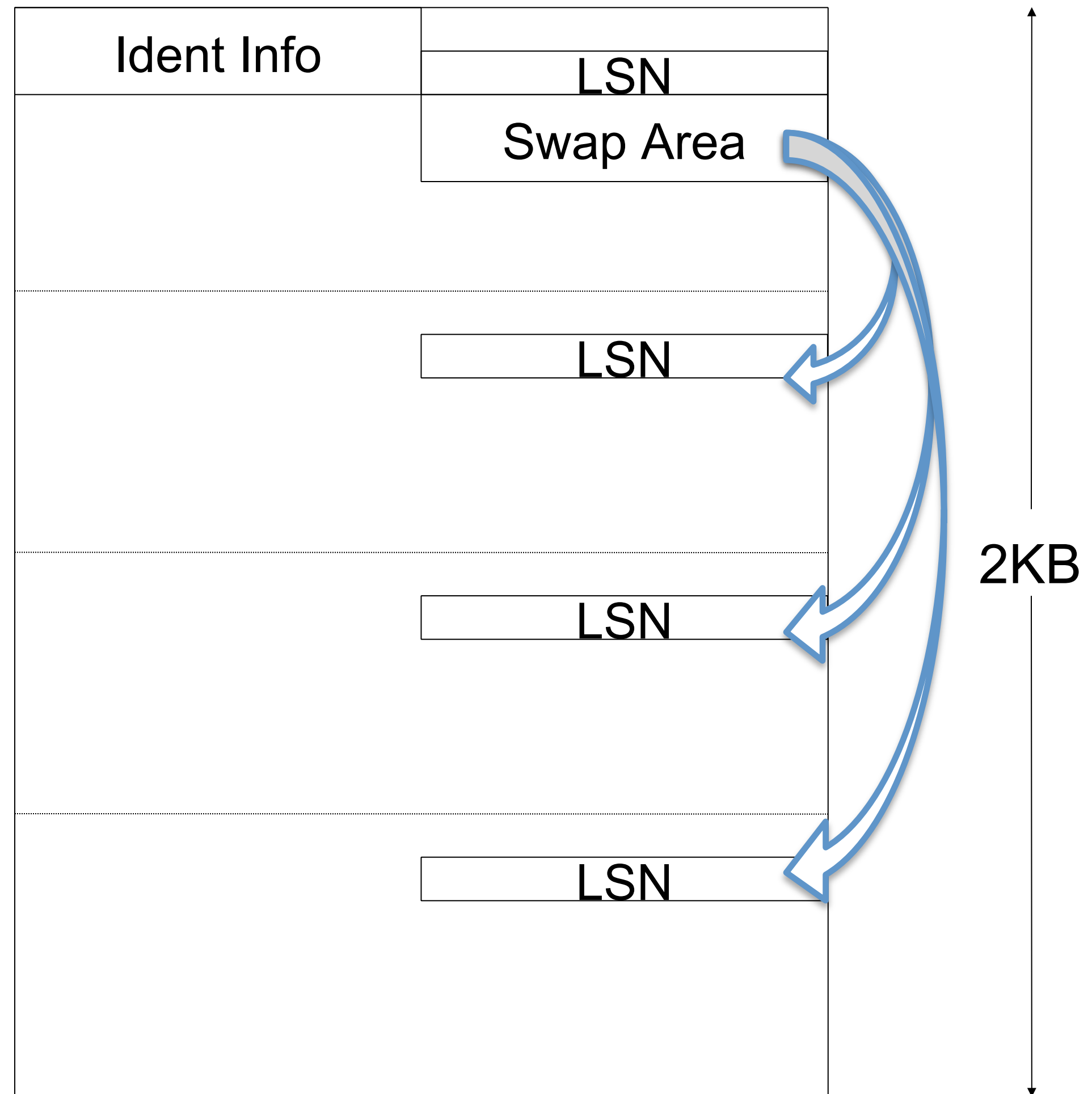
000000.DIR;1	0/0	31-JUL-2017	11:45:03.40	(RWED,RWED,RE,E)
SYSDELETE.DIR;1	0/0	31-JUL-2017	11:45:03.31	(RWED,RWED,RWED,RWED)
SYSHIDDEN.DIR;1	0/0	31-JUL-2017	11:45:03.40	(RWE,RWE,RE,)
SYSQUOTA.DIR;1	0/0	31-JUL-2017	11:45:03.31	(RWED,RWED,RWED,RWED)
SYSRECOVERY.DIR;1	0/0	31-JUL-2017	11:45:03.31	(RWED,RWED,RWED,RWED)

Note the lack of ODS-2/5 style metadata files

VAFS: How it works

- VAFS is **log-based**, not **log-structured** (Spiralog)
- All file system metadata writes are first written to a transaction log before moved to destination LBNs
- Metadata encapsulated in building block data structures like
 - **List Pages**
 - **Streams**
 - **Trees**
 - **Key-list value pairs**

Disk Page

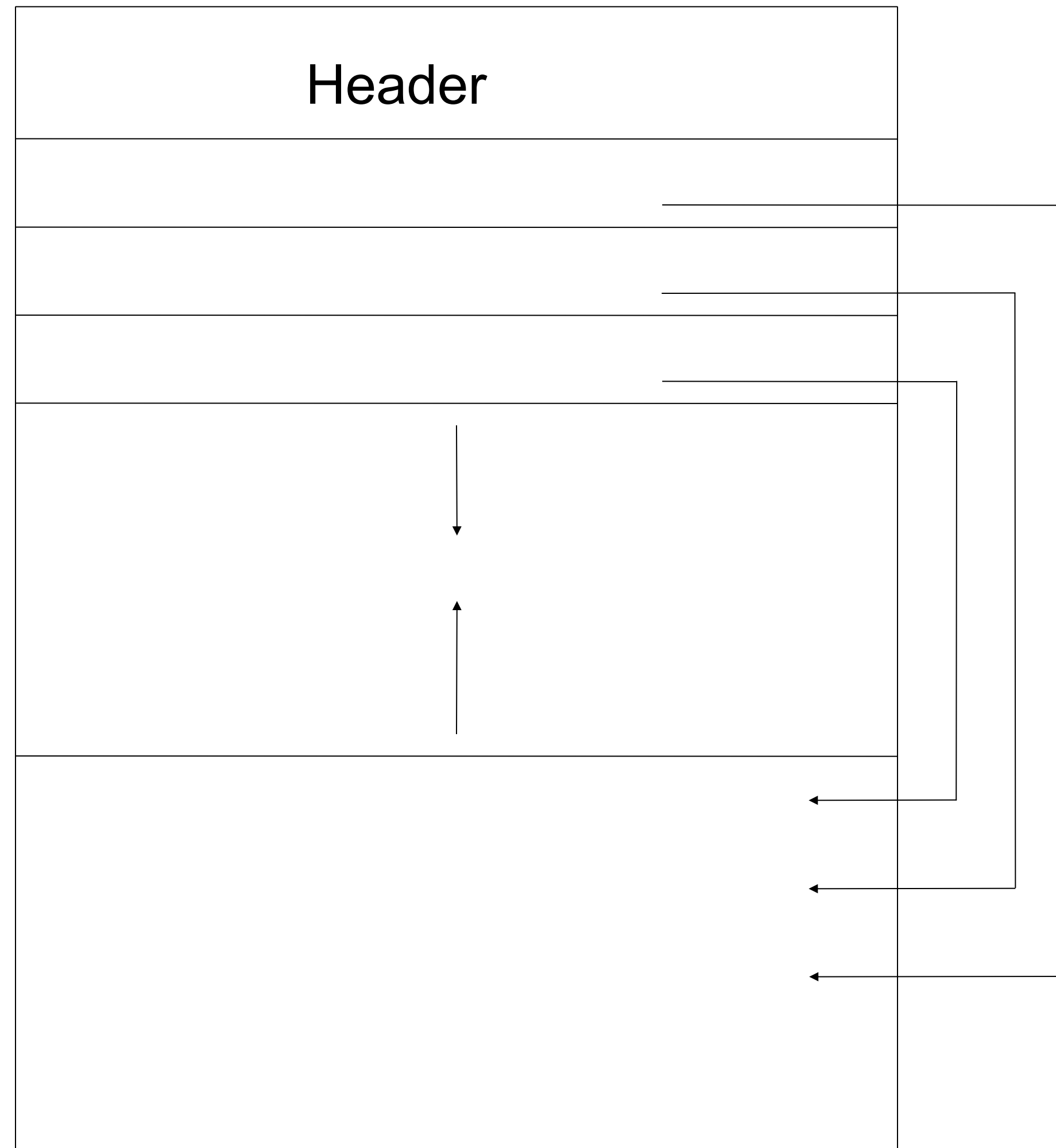


List Pages

- Ordered array of key-length value items. Most VAFS metadata is stored in **LIST PAGES**
- **LIST PAGES** have **SLOTS** which contain **STREAMS**
- Aggregated into **TREES**; leaf pages store the actual data
- Located by index entry in a parent list page
- Examples of **LIST PAGES** as **TREES**
 - Attributes (ODS-2/5 file header == VAFS tree)
 - Directories
 - Extent maps

List Page

Attribute
Value
Pairs



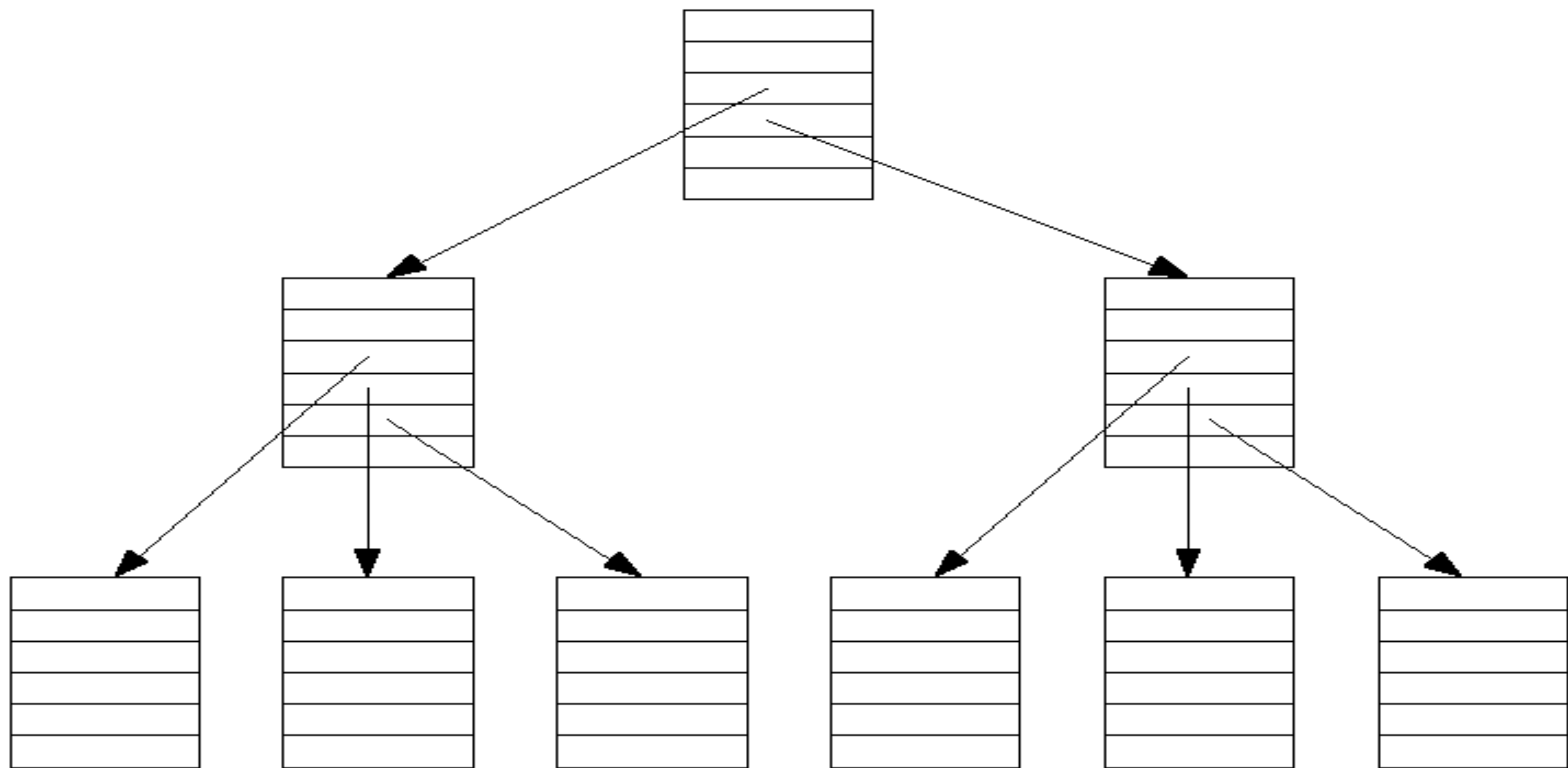
Fixed
Size Key
Prefix

Key
Remainder
& Value

Streams

- Direct: stored in a List Page as an attribute value in a **SLOT**
- Mapped: stored in List Pages via an extent tree. Root of the tree is an attribute value
- Examples of streams
 - Index file
 - Storage Bitmap
 - FID bitmap
 - Recovery log

Tree



Examples of Trees

- Directories
- Storage Bitmap Index
- FID Bitmap Index
- Storage Allocation Cache
- FID allocation Cache

Directory

- Special file type
- Directory content is a special file attribute, stored as a tree
- Directory entry
 - Key = file name, normalized Unicode + case flags
 - Value = file ID

Bitmap

- Used to allocate file IDs and free blocks
- Organized in page-size segments
- Extensible tree structure

How do we make sense of this stuff?

\$ DUMP/XFS is the answer (without it, we'd be doomed!)

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Thanks, Andy!



VAFS: Let's get started

\$ INIT <device name> /STRUCTURE = 6 <label>

- Writes an ODS-2/5-compatible home block with a tiny bit of ODS-6 info
- Does not write much of the file system infrastructure

\$ MOUNT <device name> <label>

- “First Mount” of a VAFS volume does most of the initialization
- Key structures include Home Page, Recovery Log, storage bitmap

Newly-initialized VAFS Disk Layout (10GB)

LBN	Description
0-63	ODS-compatible home blocks (with some minor VAFS info)
64-319	Reserved Recovery Log (used by MOUNT for bootstrapping recovery logs)
320-323	Home Page (Volume attributes, pointers to many important things)
324-335	MBZ
336-339	Free FID Bitmap stream
340-595	Index File Stream
596-2116	Free LBN Bitmap stream
2120-2776	Free LBN Bitmap Index
	Free FID Bitmap Index (embedded in Home Page)
2780-10840	Recovery Log (File system metadata writes land here first)

VAFS Disk Page Header (for metadata)

```
typedef struct XFS_PAGE_S
{
    uint32          checksum;
    uint32          lsn;
    XFS_SI          si;
    uint8           allocSize;
    uint8           actSize;
    XFS_PAGE_FLAGS flags;
    uint64          lbn;
    uint64          fileNum;
    uint32          mbz[3];
    uint32          swap[XFS_PAGE_SWAP_SIZE];
    uint64          data[1];
} XFS_PAGE
```

VAFS Log Sequence Number (LSN)

- Used to verify integrity of page and detect complete transactions in the log
- For a multi-block disk page, each page contains the same LSN
- LSN increases monotonically
- A series of flags in the disk page are used to identify a complete (that is, a committed to disk, transaction)
- Every page in a transaction has the same LSN; helps to verify integrity of the log entry

VAFS Page State Identifier (SI)

- Determines age of copy of page and whether or not a page in the log is written to its home location during recovery
- Used for error detection during normal operation
- Use during offline repair of volume
- Reasons for page being written include
 - Cache replacement
 - Off-node request
 - Metric-based log trimming

VAFS Home Page

- Root of tree holding the volume attributes
- All elements of file structure are linked to the home page

```
#define XFS_ATTR_VOLUME          1      /* volume attributes */
#define XFS_ATTR_INDEX          2      /* index file stream .. */
#define XFS_ATTR_INDEX_INFO     3      /* .. and stream attributes */
#define XFS_ATTR_LBNMAP         4      /* free LBN map stream .. */
#define XFS_ATTR_LBNMAP_INFO    5      /* .. and stream attributes */
#define XFS_ATTR_FIDMAP         6      /* free FID map stream .. */
#define XFS_ATTR_FIDMAP_INFO    7      /* .. and stream attributes */
#define XFS_ATTR_LBNMAP_INDEX   8      /* index on LBN map */
#define XFS_ATTR_FIDMAP_INDEX   9      /* index on FID map */
```

VAFS Home Page

```
$ DUMP/XFS /BLOCK= (START:320,COUNT:4) <device>
```

XFS Metadata Page

XFS page header

```
Page size (blocks):    4 used, 4 allocated
Page address:         LBN 320
Page state:           AllocSeq = 503, UpdateSeq = 30, LSN = 57
Parent file number:   5
Page log flags:       file lock
```

XFS list page header

```
Page type:            attributes
Page flags:           <none specified>
Structure version:    1/1 (major/minor)
List page size:       1984 bytes, 12 slots in use, 0 deleted
Free space (bytes):   48 free on top, 0 deleted
```


Index File Info

Formatted List Page Slots

List Page Slot 0, flags: <none specified>

Stream type: unspecified

8 byte key: (1) - volume attributes (#define XFS_ATTR_VOLUME 1 /* volume attributes */)

208 byte value:

```
00000000 00000000 00000000 00000800 00000800 00000200 E944A850 01020101 .....P`Dé..... 000000
00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 ..... 000020
00000000 00500000 00000000 00000000 00000000 00000000 00000000 00000000 .....P.... 000040
00000000 00000040 00000000 00500000 00000000 00500000 00000000 00500000 ..P.....P.....P.....@..... 000060
00B1ED7A E944CF60 00000000 00000D80 00000D80 00000000 00000000 00000040 @.....`İDézít. 000080
00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 ..... 0000A0
                                00000000 00000000 00000000 00000000 ..... 0000C0
```

List Page Slot 1, flags: mapped

Stream type: metadata

8 byte key: (2) - index file stream (#define XFS_ATTR_INDEX 2 /* index file stream .. */)

Formatted extent list on following page

List Page Slot 2, flags: <none specified>

Stream type: unspecified

8 byte key: (3) - index file stream info (#define XFS_ATTR_INDEX_INFO 3 /* .. and stream attributes */)

Allocated length: 131072 (0000000000020000) bytes (256 blocks)

Data length: 131072 (0000000000020000) bytes (256 blocks)

Highest written: 0 (0000000000000000) bytes (0 blocks)

Free LBN/Free FID map streams

List Page **Slot 3**, flags: mapped

Stream type: metadata

8 byte key: (4) - free LBN map stream (#define XFS_ATTR_LBNMAP 4 /* free LBN map stream .. */)

Formatted extent list on following page

List Page Slot 4, flags: <none specified>

Stream type: unspecified

8 byte key: (5) - free LBN map stream info (#define XFS_ATTR_LBNMAP_INFO 5 /* .. and stream attributes */)

Allocated length: 778240 (0000000000BE00) bytes (1520 blocks)

Data length: 778240 (0000000000BE00) bytes (1520 blocks)

Highest written: 0 (00000000000000) bytes (0 blocks)

List Page **Slot 5**, flags: mapped

Stream type: metadata

8 byte key: (6) - free FID map stream (#define XFS_ATTR_FIDMAP 6 /* free FID map stream .. */)

Formatted extent list on following page

List Page Slot 6, flags: <none specified>

Stream type: unspecified

8 byte key: (7) - free FID map stream info (#define XFS_ATTR_FIDMAP_INFO 7 /* .. and stream attributes */)

Allocated length: 2048 (000000000000800) bytes (4 blocks)

Data length: 2048 (000000000000800) bytes (4 blocks)

Highest written: 0 (00000000000000) bytes (0 blocks)

List Page Slot 7, flags: <none specified>

Stream type: unspecified

8 byte key: (8) - LBN map index (#define XFS_ATTR_LBNMAP_INDEX 8 /* index on LBN map */)

Formatted list page value on following page

Recovery Log streams

List Page Slot 8, flags: <none specified>
Stream type: unspecified
8 byte key: (9) - FID map index
Formatted list page value on following page

List Page Slot 9, flags: <none specified>
Stream type: unspecified
8 byte key: (24) - volume label
14 byte value:

0024 00240053 004D0056 00240024 \$.\$.V.M.S.\$.\$. 000000

List Page **Slot 10**, flags: mapped
Stream type: metadata
8 byte key: (00000200000092C) - **Recovery log stream 1174**
Formatted extent list on following page

List Page Slot 11, flags: <none specified>
Stream type: unspecified
8 byte key: (00000200000092D) - **Recovery log stream 1174** info
Allocated length: 4124672 (0000000003EF000) bytes (8056 blocks)
Data length: 4124672 (0000000003EF000) bytes (**8056 blocks**)
Highest written: 0 (0000000000000000) bytes (0 blocks)

Index File Stream Info

List page **slot 1** extent list value

XFS list page header

Page type: extent
Page flags: <none specified>
Structure version: 1/1 (major/minor)
List page size: 128 bytes, 1 slots in use, 0 deleted
Free space (bytes): 80 free on top, 0 deleted

Formatted List Page Slots

List Page Slot 0, flags: <none specified>
Stream type: unspecified
8 byte extent key: SBO = 131071 (000000000001FFFF), VBN 256
Extent pointer: length = 131072 (0000000000020000) bytes (**256 blocks**)
LBN 340

Free LBN Bitmap info

List page **slot 3** extent list value

XFS list page header

Page type: extent
Page flags: <none specified>
Structure version: 1/1 (major/minor)
List page size: 128 bytes, 1 slots in use, 0 deleted
Free space (bytes): 80 free on top, 0 deleted

Formatted List Page Slots

List Page Slot 0, flags: <none specified>
Stream type: unspecified
8 byte extent key: SBO = 778239 (00000000000BDFFF), VBN 1520
Extent pointer: length = 778240 (00000000000BE000) bytes (**1520 blocks**)
LBN 596

Free FID bitmap info

List page **slot 5** extent list value

XFS list page header

Page type: extent
Page flags: <none specified>
Structure version: 1/1 (major/minor)
List page size: 128 bytes, 1 slots in use, 0 deleted
Free space (bytes): 80 free on top, 0 deleted

Formatted List Page Slots

List Page Slot 0, flags: <none specified>
Stream type: unspecified
8 byte extent key: SBO = 2047 (000000000000007FF), VBN 4
Extent pointer: length = 2048 (00000000000000800) bytes (**4 blocks**)
LBN 336

Recovery log info

List page **slot 10** extent list value

XFS list page header

Page type: extent
Page flags: <none specified>
Structure version: 1/1 (major/minor)
List page size: 128 bytes, 1 slots in use, 0 deleted
Free space (bytes): 80 free on top, 0 deleted

Formatted List Page Slots

List Page Slot 0, flags: <none specified>
Stream type: unspecified
8 byte extent key: SBO = 4124671 (00000000003EEFFF), VBN 8056
Extent pointer: length = 4124672 (00000000003EF000) bytes (**8056 blocks**)
LBN 2780

```
$ create $1$dga220:[0,0]bootcamp.txt
```

Everyone should use Host-Based Minimerge with Host-based Volume Shadowing!

```
Exit
```

To find the directory of [000000], we need to know two things

1) The FID of the MFD [000000] -----→ (4,4,0)

2) The starting block of the Index Stream -→ LBN 340

The VBN of a file's index page (in ODS-2 terms, the file header) is
cluster factor * (File number - 1)

For the MFD, it's VBN = $4 * (4 - 1) = 12$

The VBN is 12, which must be added to the LBN of the starting block of the Index Stream
Thus, we have $340 + 12 = 352 = \text{root of list page of the index stream for FID } (4,4,0)$


```
$ dump/xf/b1=(s:352,c:4) $1$dga220: /nopage
```

```
Logical block number 352 (00000160), 2048 (0800) bytes
```

XFS Metadata Page

XFS page header

```
Page size (blocks): 2 used, 4 allocated  
Page address: LBN 352  
Page state: AllocSeq = 503, UpdateSeq = 3, LSN = 29  
Parent file number: 4  
Page log flags: file lock
```

XFS list page header

```
Page type: attributes  
Page flags: <none specified>  
Structure version: 1/1 (major/minor)  
List page size: 960 bytes, 4 slots in use, 0 deleted  
Free space (bytes): 144 free on top, 0 deleted
```

Formatted List Page Slots

```
List Page Slot 0, flags: <none specified>
  Stream type:          unspecified
  8 byte key:           (30) - common object attributes
  Attributes version: 1/1 (major/minor)
  Object ID:            4, 4
  Object type:          (2) - directory
  File entry linkcount: 1
  Object flags:         <none specified>
  Perf. options:        <none specified>
  Cache control:        00000111
  Last access date:    31-JUL-2017 11:45:03.40
  Creation date:       31-JUL-2017 11:45:03.40
  Revision date:       31-JUL-2017 11:45:03.40
  Last attribute change date: 31-JUL-2017 11:45:03.40
  Backup date:         <none specified>
  Expiration date:     <none specified>
  Revision number:     0
  User sequence number: 1
  File owner UIC:      [SYSTEM]
  File protection:     S:RWED, O:RWED, G:RE, W:E
  ACL length:          0
  Journal control flags: <none specified>
  Active recovery units: None
```

```

List Page Slot 1, flags: <none specified>
  Stream type:          unspecified
  48 byte key:
00040000 00000004 00000000 0000001F ..... 000000
00300030 002E0044 00300030 00300030 0.0.0.0.D...0.0. 000010
FFFE0000 00000000 00490052 0000FFFF ....R.I.....p. 000020
  No value

```

```

List Page Slot 2, flags: <none specified>
  Stream type:          unspecified
  8 byte key:          (44) - access control list
  112 byte value:
55020006 0000005E 55555555 550F0855 U..UUUUU^.....U 000000
00010001 0008000C 00000000 00000000 ..... 000010
00000000 0000000C 00080802 00060002 ..... 000020
FFF0FFFF FFE0FFFF FFE00014 00090000 .....à...à...ď. 000030
00140000 00000008 0017FFFF FFF0FFFF ..ď..... 000040
55550000 00000000 00000000 00000010 .....UU 000050
55555555 55555555 55555555 55555555 UUUUUUUUUUUUUUUUU 000060

```



List Page Slot 3, flags: <none specified>
Stream type: unspecified
8 byte key: (50) - directory tree
Formatted list page value on following page

List page index 3 value

XFS list page header

Page type: directory
Page flags: <none specified>
Structure version: 1/1 (major/minor)
List page size: 448 bytes, 6 slots in use, 0 deleted
Free space (bytes): 48 free on top, 0 deleted

Formatted List Page Slots

List Page Slot 0, flags: <none specified>
Stream type: unspecified
30 byte name key: 000000.DIR;1
16 byte value:
00000000 00000002 00040000 00000004 000000

List Page Slot 1, flags: <none specified>
Stream type: unspecified
34 byte name key: BOOTCAMP.TXT;1
16 byte value:
00000000 00000001 60940000 00000018`..... 000000

List Page Slot 2, flags: <none specified>
Stream type: unspecified
36 byte name key: SYSDELETE.DIR;1
16 byte value:
00000000 00000002 00060000 00000006 000000

List Page Slot 3, flags: <none specified>
Stream type: unspecified
36 byte name key: SYSHIDDEN.DIR;1
16 byte value:
00000000 00000002 00070000 00000007 000000

List Page Slot 4, flags: <none specified>
Stream type: unspecified
34 byte name key: SYSQUOTA.DIR;1
16 byte value:
00000000 00000002 00080000 00000008 000000

List Page Slot 5, flags: <none specified>
Stream type: unspecified
42 byte name key: SYSRECOVERY.DIR;1
16 byte value:
00000000 00000002 00090000 00000009 000000

Now to find the actual data on the disk for our newly-created file

```
$ dir $1$dga220:[0,0]bootcamp.txt/file
```

```
Directory $1$DGA220:[0,0]
```

```
BOOTCAMP.TXT;1          (24,24724,0)
```

```
Total of 1 file.
```

The VBN of a file's index page (in ODS-2 terms, the file header) is
cluster factor * (File number - 1)

For our file, it's $VBN = 4 * (24 - 1) = 92$

The VBN is 92, which must be added to the LBN of the starting block of the Index Stream
Thus, we have $340 + 92 = 432 = \text{root of list page of the index stream for our file}$

```
$ dump/xfs/bl=(s:432,c:4) $1$dga220: /nopage
```

```
Logical block number 432 (000001B0), 2048 (0800) bytes
```

XFS Metadata Page

XFS page header

```
Page size (blocks):    2 used, 4 allocated
Page address:         LBN 432
Page state:           AllocSeq = 503, UpdateSeq = 4, LSN = 46
Parent file number:   24
Page log flags:       file lock
```

XFS list page header

```
Page type:            attributes
Page flags:           <none specified>
Structure version:    1/1 (major/minor)
List page size:       960 bytes, 6 slots in use, 0 deleted
Free space (bytes):   456 free on top, 0 deleted
```

Formatted List Page Slots

```
List Page Slot 0, flags: <none specified>
  Stream type:          unspecified
  8 byte key:          (30) - common object attributes
  Attributes version:  1/1 (major/minor)
  Object ID:           24, 24724
  Object type:         (1) - file
  File entry linkcount: 1
  Object flags:        <none specified>
  Perf. options:       <none specified>
  Cache control:       00000111
  Last access date:    21-SEP-2017 10:57:25.37
  Creation date:       21-SEP-2017 10:57:25.37
  Revision date:       21-SEP-2017 10:58:00.00
  Last attribute change date: 21-SEP-2017 10:57:25.37
  Backup date:         <none specified>
  Expiration date:     <none specified>
  Revision number:     0
  User sequence number: 1
  File owner UIC:      [SYSTEM]
  File protection:     S:RWED, O:RWED, G:RE, W:
  ACL length:          0
  Journal control flags: <none specified>
  Active recovery units: None
```



```

List Page Slot 1, flags: <none specified>
  Stream type:      unspecified
  52 byte key:
00040000 00000004 00000000 0000001F ..... 000000
00430041 004D0050 0042004F 004F0054 T.O.B.P.M.A.C. 000010
0000FFFF FFFE0000 002E0054 00580054 T.X.T....p.... 000020
                00000000 00000000 ..... 000030

  No value

```

```

List Page Slot 2, flags: <none specified>
  Stream type:      unspecified
  8 byte key:      (40) - RMS file attributes
  VAX-11 RMS attributes
    Record type:          Variable
    File organization:    Sequential
    Record attributes:    Implied carriage control
    Record size:          74
    Highest block:        64
    End of file block:    1
    End of file byte:     76
    Bucket size:          0
    Fixed control area size: 0
    Maximum record size:  0
    Default extension size: 0
    Global buffer count:  0
    Global buffer count V8.3+: 0
    Global buffer flags V8.3+: Count
    Directory version limit: 0
  Extended record attributes: 0000000000000000
  Length hint: 0000000000000000, 0000000000000000

```

List page slot 4 extent list value

XFS list page header

Page type: extent
Page flags: <none specified>
Structure version: 1/1 (major/minor)
List page size: 128 bytes, 2 slots in use, 1 deleted
Free space (bytes): 48 free on top, 32 deleted

Formatted List Page Slots

List Page Slot 0, flags: <none specified>
Stream type: unspecified
8 byte extent key: SBO = 2047 (000000000000007FF), VBN 4
Extent pointer: length = 2048 (00000000000000800) bytes (4 blocks)
LBN 11100

```
$ dump /noxfs/block=(start:11100,count:1) $1$dga220:
```

```
Dump of device $1$DGA220: on 21-SEP-2017 11:41:06.92
```

```
Logical block number 11100 (00002B5C), 512 (0200) bytes
```

```
6C756F68 7320656E 6F797265 7645004A J.Everyone shoul 000000
64657361 422D7473 6F482065 73752064 d use Host-Based 000010
20687469 77206567 72656D69 6E694D20 Minimerge with 000020
6D756C6F 56206465 7361622D 74736F48 Host-based Volum 000030
0000FFFF 21676E69 776F6461 68532065 e Shadowing!.... 000040
00000000 00000000 00000000 00000000 ..... 000050
00000000 00000000 00000000 00000000 ..... 000060
```

%x4A = 74. = record length

RMS sequential file records are prefixed with a 16-bit count

```
$ dump/file/head/form $1$dga220:[0,0]bootcamp.txt/block=count=0/nopage
```

File Header

Header area

```
Identification area offset:      40
Map area offset:                 100
Access control area offset:     255
Reserved area offset:           255
Extension segment number:       0
Structure level and version:    64, 0
File identification:             (24,24724,0)
Extension file identification:   (0,0,0)
VAX-11 RMS attributes
Record type:                     Variable
File organization:              Sequential
Record attributes:              Implied carriage control
Record size:                    74
Highest block:                  4
End of file block:              1
End of file byte:               76
Bucket size:                   0
Fixed control area size:        0
Maximum record size:            0
Default extension size:         0
Global buffer count:            0
Global buffer count V8.3+:      0
Global buffer flags V8.3+:      Count
Directory version limit:        0
File characteristics:           Contiguous
Caching attribute:              Writethrough
Map area words in use:          2
Access mode:                    0
File owner UIC:                 [SYSTEM]
File protection:                S:RWED, O:RWED, G:RE, W:
Back link file identification:   (4,4,0)
Journal control flags:          <none specified>
Active recovery units:          None
File entry linkcount:           0
Highest block written:          4
Client attributes:              None
```

Identification area

File name: BOOTCAMP.TXT;1
Revision number: 0
Creation date: 21-SEP-2017 10:57:25.37
Revision date: 21-SEP-2017 10:58:00.00
Expiration date: <none specified>
Backup date: <none specified>

Map area

Retrieval pointers

Count: 5 LBN: 0

Checksum: 10323

```
$ dir/col=1
```

```
Directory $1$DGA240:[0,0]
```

```
000000.DIR;1
```

```
FILE.1;1
```

```
FILE.2;1
```

```
FILE.3;1
```

```
FILE.4;1
```

```
FOO.BAR;1
```

```
SYSDELETE.DIR;1
```

```
SYSHIDDEN.DIR;1
```

```
SYSQUOTA.DIR;1
```

```
SYSRECOVERY.DIR;1
```

```
$ dump/xfss/block=(s:352,c:4) $1$dga240:/nopage
```

```
Logical block number 352 (00000160), 2048 (0800) bytes
```

XFS Metadata Page

XFS page header

```
Page size (blocks):    2 used, 4 allocated
Page address:         LBN 352
Page state:           AllocSeq = 503, UpdateSeq = 6, LSN = 56
Parent file number:   4
Page log flags:       file lock
```

XFS list page header

```
Page type:            attributes
Page flags:           <none specified>
Structure version:    1/1 (major/minor)
List page size:       960 bytes, 4 slots in use, 0 deleted
Free space (bytes):   144 free on top, 0 deleted
```

Formatted List Page Slots

```
List Page Slot 0, flags: <none specified>
Stream type:          unspecified
8 byte key:          (30) - common object attributes
Attributes version: 1/1 (major/minor)
Object ID:           4, 4
Object type:         (2) - directory
File entry linkcount: 1
Object flags:        <none specified>
Perf. options:       <none specified>
Cache control:       00000111
Last access date:    27-JUL-2017 14:12:51.04
Creation date:       27-JUL-2017 14:12:51.04
Revision date:       27-JUL-2017 14:12:51.04
Last attribute change date: 27-JUL-2017 14:12:51.04
Backup date:         <none specified>
Expiration date:     <none specified>
Revision number:     0
User sequence number: 1
File owner UIC:      [SYSTEM]
File protection:     S:RWED, O:RWED, G:RE, W:E
ACL length:          0
Journal control flags: <none specified>
Active recovery units: None
```



```

List Page Slot 1, flags: <none specified>
  Stream type:          unspecified
  48 byte key:
00040000 00000004 00000000 0000001F ..... 000000
00300030 002E0044 00300030 00300030 0.0.0.0.D...0.0. 000010
FFFE0000 00000000 00490052 0000FFFF ....R.I.....p. 000020
  No value

```

```

List Page Slot 2, flags: <none specified>
  Stream type:          unspecified
  8 byte key:          (44) - access control list
  112 byte value:
55020006 0000005E 55555555 550F0855 U..UUUUU^.....U 000000
00010001 0008000C 00000000 00000000 ..... 000010
00000000 0000000C 00080802 00060002 ..... 000020
FFF0FFFF FFE0FFFF FFE00014 00090000 .....à...à...đ. 000030
00140000 00000008 0017FFFF FFF0FFFF ..đ..... 000040
55550000 00000000 00000000 00000010 .....UU 000050
55555555 55555555 55555555 55555555 UUUUUUUUUUUUUUUUU 000060

```



List Page Slot 3, flags: <none specified>
Stream type: unspecified
8 byte key: (50) - directory tree
Formatted list page value on following page

List page slot 3 value

XFS list page header

Page type: **directory tree**
Page flags: index
Structure version: 1/1 (major/minor)
List page size: 448 bytes, 1 slots in use, 0 deleted
Free space (bytes): 408 free on top, 0 deleted

Formatted List Page Slots

List Page Slot 0, flags: <none specified>
Stream type: unspecified
8 byte key: FFFFFFFFFFFFFFFFFF
Index pointer: **LBN 11112**

```
$ dump/xfs/block=(s:11112,c:4) $1$dga240:/nopage
```

```
Logical block number 11112 (00002B68), 2048 (0800) bytes
```

```
[...]
```

```
XFS list page header
```

```
Page type:          directory  
Page flags:         <none specified>  
Structure version: 1/1 (major/minor)  
List page size:    960 bytes, 13 slots in use, 3 deleted  
Free space (bytes): 248 free on top, 136 deleted
```

```
Formatted List Page Slots
```

```
List Page Slot 0, flags: <none specified>  
Stream type:           unspecified  
30 byte name key:    000000.DIR;1  
16 byte value:  
00000000 00000002 00040000 00000004 ..... 000000
```

```
List Page Slot 1, flags: <none specified>  
Stream type:           unspecified  
22 byte name key:    FILE.1;1  
16 byte value:  
00000000 00000001 A6E20000 0000001B .....âŠ..... 000000
```

```
List Page Slot 2, flags: <none specified>  
Stream type:           unspecified  
22 byte name key:    FILE.2;1  
16 byte value:  
00000000 00000001 A6E30000 0000001C .....ãŠ..... 000000
```



```

List Page Slot 3, flags: <none specified>
  Stream type:      unspecified
  22 byte name key: FILE.3;1
  16 byte value:
00000000 00000001 A6E50000 00000018 .....âš..... 000000

List Page Slot 4, flags: <none specified>
  Stream type:      unspecified
  22 byte name key: FILE.4;1
  16 byte value:
00000000 00000001 A6E70000 0000001E .....çŠ..... 000000

List Page Slot 5, flags: <none specified>
  Stream type:      unspecified
  24 byte name key: FOO.BAR;1
  16 byte value:
00000000 00000001 56B30000 0000001D .....³V..... 000000

List Page Slot 6, flags: <none specified>
  Stream type:      unspecified
  36 byte name key: SYSDELETE.DIR;1
  16 byte value:
00000000 00000002 00060000 00000006 ..... 000000

List Page Slot 7, flags: <none specified>
  Stream type:      unspecified
  36 byte name key: SYSHIDDEN.DIR;1
  16 byte value:
00000000 00000002 00070000 00000007 ..... 000000

List Page Slot 8, flags: <none specified>
  Stream type:      unspecified
  34 byte name key: SYSQUOTA.DIR;1
  16 byte value:
00000000 00000002 00080000 00000008 ..... 000000

List Page Slot 9, flags: <none specified>
  Stream type:      unspecified
  42 byte name key: SYSRECOVERY.DIR;1
  16 byte value:
00000000 00000002 00090000 00000009 ..... 000000

```

Thank You

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