Surviving the Out of Memory Killer

Dave Hansen & Balbir Singh

OOF Condition

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- **How do we choose the right passenger?**
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thanks to Andries Brouwer

Out of Memory

- **From the kernel's perspective:**
  - "Someone asked for memory and I'm not making any progress helping"
  - We fell under `min_free_kbytes`, scanned memory 6 times, and have not been able to get back above the limit
- **... so we are now going to start killing things**
- **The YKWTLOMFTLAYPHTD Killer lacks the ring of "OOM Killer"**
  - (The Kernel Was Too Low On Memory For Too Long And Your Process Had To Die Killer)

Keeping Score

- **Good News**
  - You have been running for a long time
  - You are root (really CAP_SYS_ADMIN|RAWIO)
- **Bad News**
  - You are a niced process
  - You use a lot of memory (RSS)
  - Your children use a lot of memory

Common Concerns

- There was collateral damage – it killed the “wrong” thing
- It should have never triggered
- It should have triggered faster
- It should have triggered slower

Out of Memory Killer

- **How do you know when it strikes?**
- **Normal causes:**
  - All the memory/swap really is gone
    - Leaks in kernel or userspace?
  - I/O is too slow to swap or write out*
  - The kernel let too much get dirty*
  - Too little memory is reclaimable*
  - The kernel is being stupid
- **Not necessarily indicative of a bug... anywhere**

User Perspectives

- **High Performance Computing**
  - I will take as much memory can be given
  - P.S. Please tell me how much memory that is
  - P.S.S. Swapping is the devil
- **Enterprise (App/DB/Web servers)**
  - Applications do their own memory management
  - If the system gets low on memory, I want the kernel to tell me, and I'll give some of mine back
- **Desktop**
  - When OpenOffice/Firefox blows up, please just kill it quickly, I'll reopen it in a minute
  - P.S. Please don't kill sshd

Memory Reclaim

- **The Linux Philosophy:**
  - ➢ A free page of RAM is a wasted page of RAM
  - ➢ Implication: you will always eventually fill up memory with disk caches
- **Being out of memory is normal!**
- **No free memory? Scan the least-recently-used list (LRU):**
  1) Scan each page in memory (oldest first)
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Reclaim Speedbumps

- **Pages that can not be reclaimed**
  - Dirty pages, or `malloc()` with no swap
  - `mlock()`, `shm`, slab, `task_struct`
- **Best page to reclaim is a needle in a haystack**
  - 1991 – i386, 16 MHz, 4MB RAM, 4k pages
    - 1,024 pages to scan
  - 2009 – x86_64, 2 GHz, 4GB RAM, 4k pages
    - 1,048,576 pages to scan
- **The reclaim job continues to get harder**
- **If too many speedbumps stop progress -- OOM**

Beat the LRU into shape

- **Never run out of memory, never reclaim, never look at the LRU**
- **Keep troublesome pages off the LRU lists**
  - Right decisions get made faster
  - hugetlbfs, split LRU (~2.6.28)
- **Mitigate other LRU speed bumps**
  - Tune dirty_bytes sysctl
- **Split up the LRU lists**
  - Each NUMA node has its own LRU list(s)
  - Use NUMA machines and kernels or fakenuma=

If you can't beat 'em...

join 'em and make your own LRU

cgroups

- **Kernel-enforced task grouping**
  - “cpusets on steroids”
  - Task grouping specified from userspace
- **Easy-to-develop “controllers”**
  - Care only about cgroups – not individual tasks

cgroups

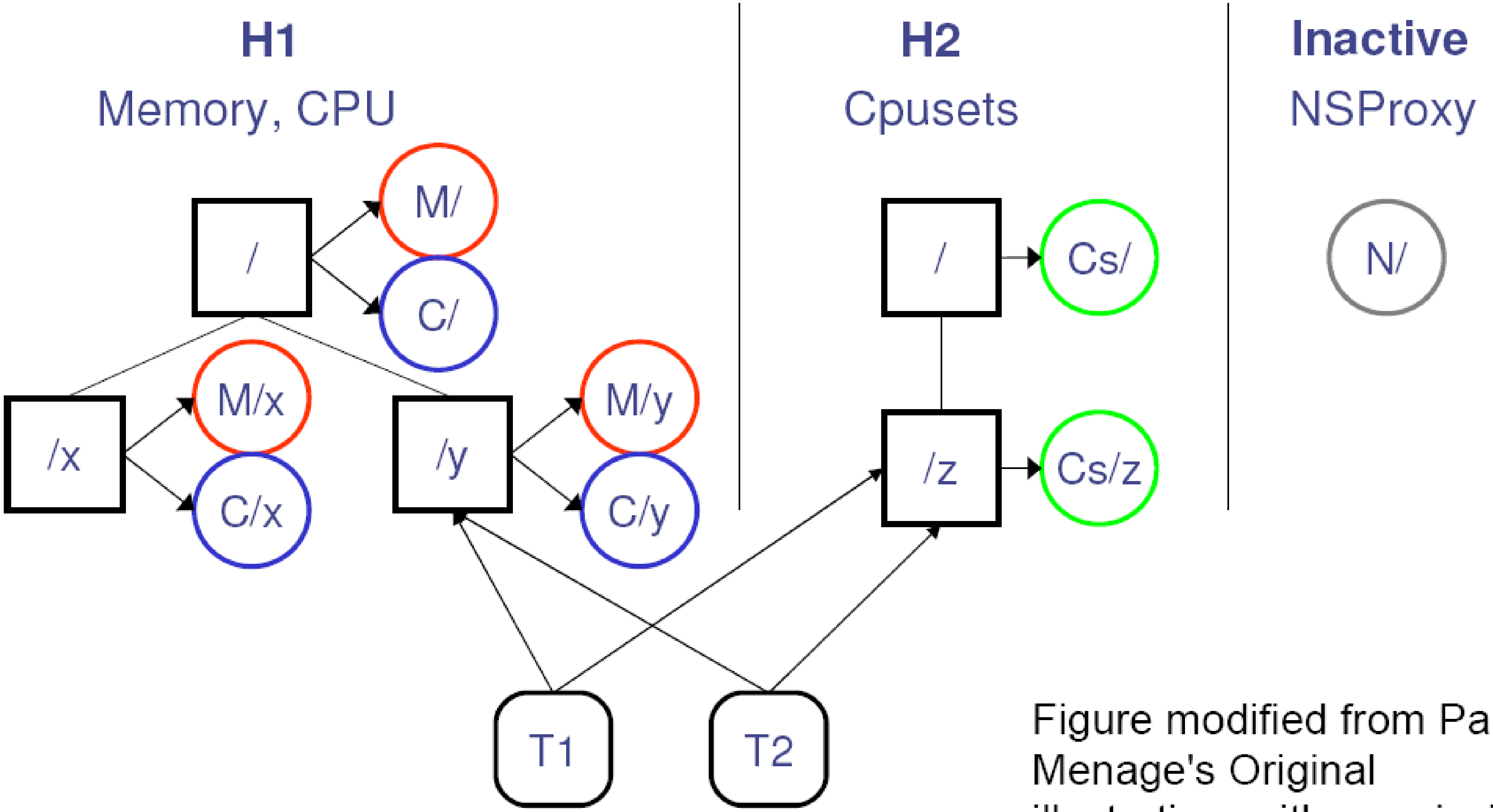


Figure modified from Paul Menage's Original illustration, with permission

Memory Controller

- **Built on top of cgroups**
- **Private LRU per cgroup**
- **Uses**
  - Enforce fairness, but allow workload flexibility
  - Contain memory hogs
  - Segregate sensitive processes
  - Containers
- **Tracks RSS, page cache, swap cache**
- **Enforces limits on memory and swap usage**
- **Individual groups can OOM**

Memory Controller

- **Conventional wisdom**
  - When the system is OOM, it is in real trouble
  - Last thing we want to do is ask userspace either what to kill or to get its help
- **Per-cgroup OOMs change all that**
  - OOM is no longer global – healthy apps can help
- **Kernel can take action against cgroups rather than individual tasks**
  - Kill whole cgroup
  - Reduce cgroup resources

Memory Controller

- **Requires extra accounting**
  - Effectively bloats **`struct page`**, or
  - Accounting costs extra CPU overhead
- **Requires unusual setup above and beyond a normal system**
- **Does not limit kernel memory use**
  - dcache, inode cache, task struct, etc...

Userspace OOM Control

- **Requirement comes from “The Enterprise”**
- **JVM, App/DB/Web Server, workload managers**
  - All do their own memory management
  - Not reflected in kernel's LRU
  - `madvise()` not finely grained-enough
- **Kernels are dumb, applications are smart**
  - Apps are a better position to enforce policies
  - Kernel has no idea about SLAs, etc...

Other Helpful Features

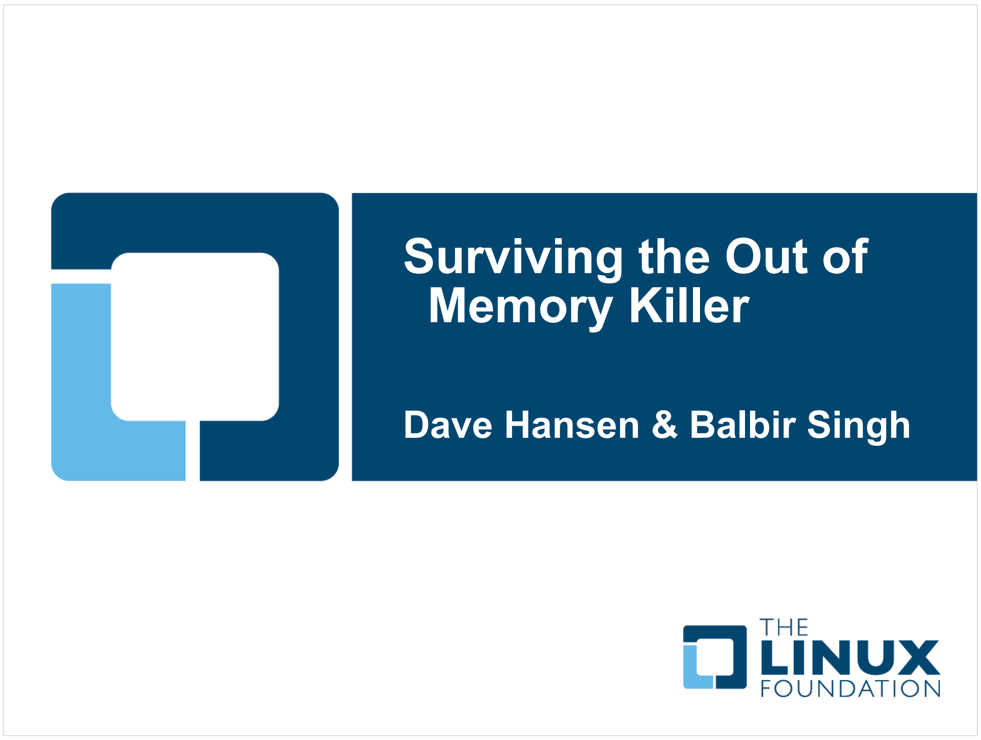
- **kernelcore= (2.6.23)**
  - Specifies ceiling on kernel memory for “non-movable allocations”
  - Inherently controls what the memory controller can not
- **oom_adj / oom_score**
  - Documented ~2.6.18, around longer than that
  - -17 adjustment “disables” OOM for a task
  - Can reduce collateral damage
  - Does not currently exist at cgroup level

Help Needed

- Who has their own OOM code?
- Does using cgroups help having OOMs?
- Does `oom_adj` reduce collateral damage?
- Is swap control effective in preserving consistent application performance?
- Can applications help the kernel during OOM?
- Are any new statistics needed to help applications make OOM decisions?
- What kinds of notifications are preferred?

Further reading

- http://linux-mm.org/OOM
- Documentation/cgroups.txt



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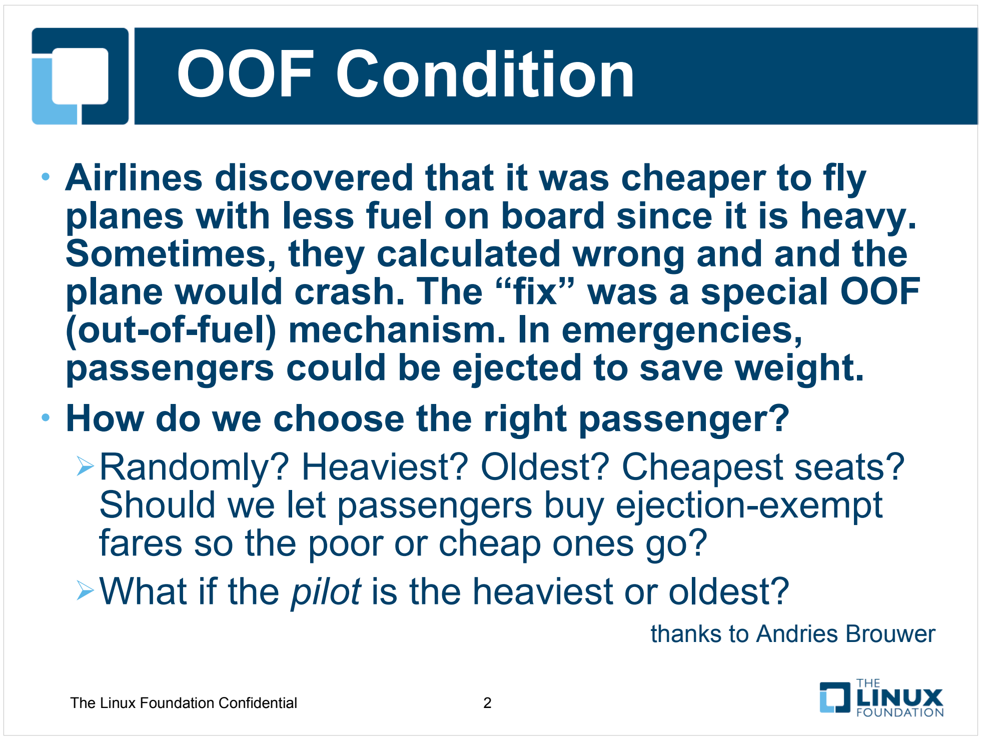

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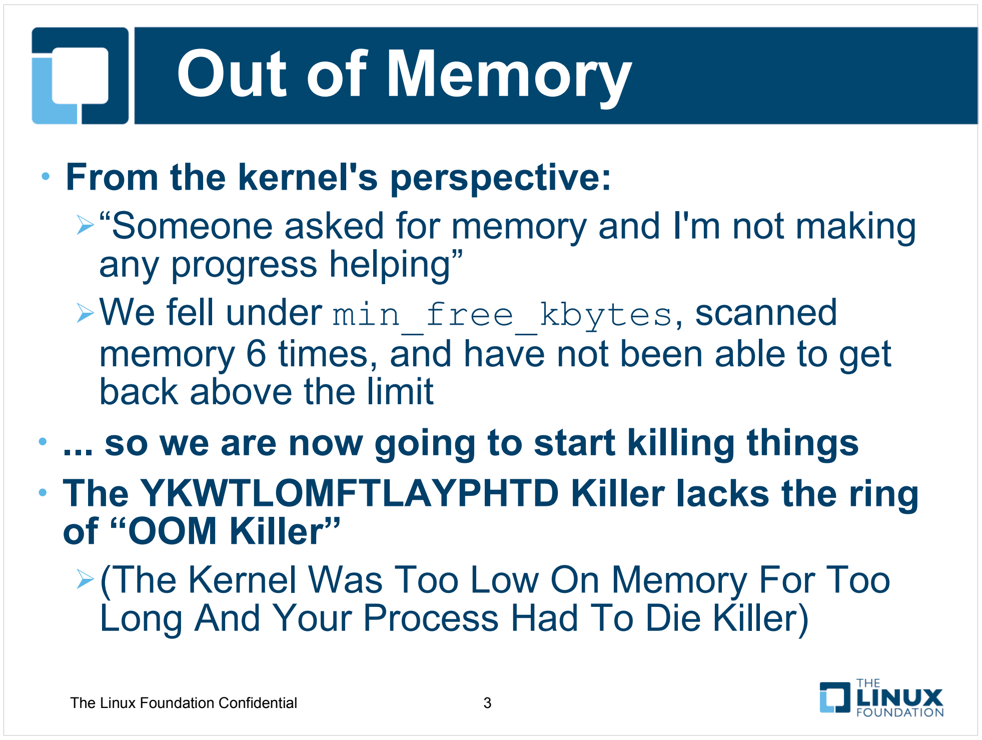

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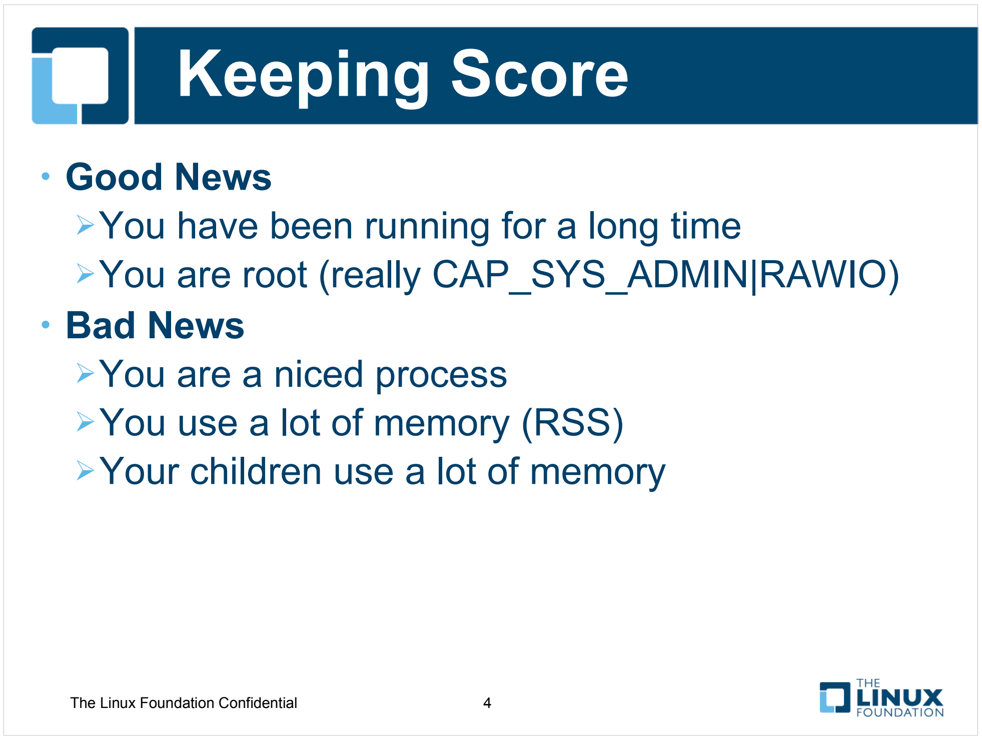

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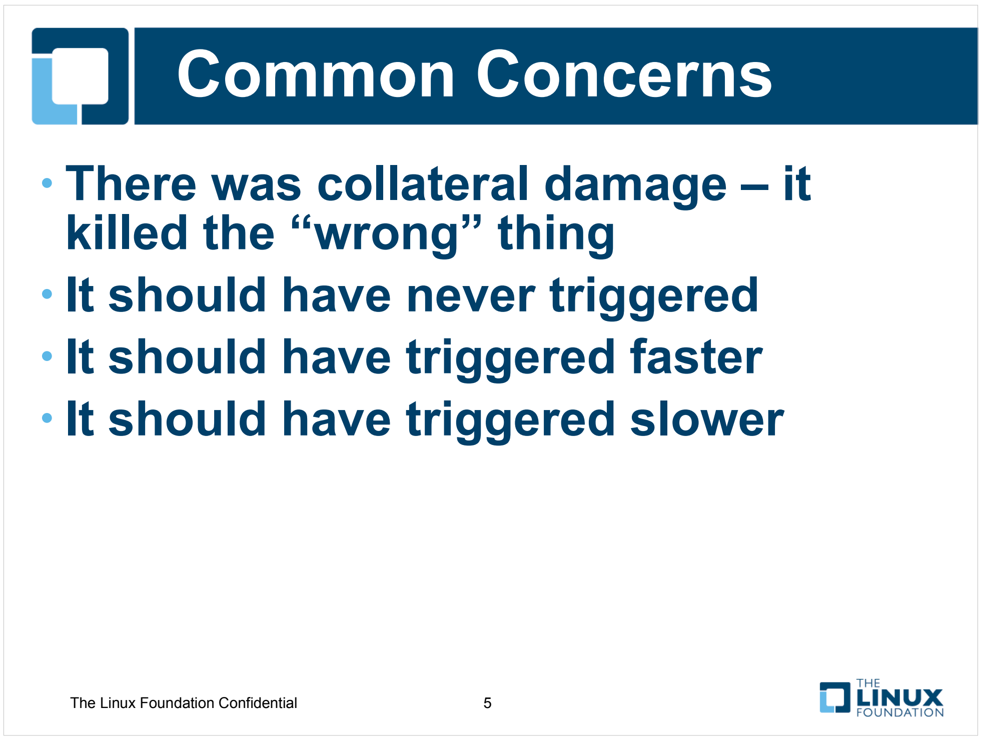

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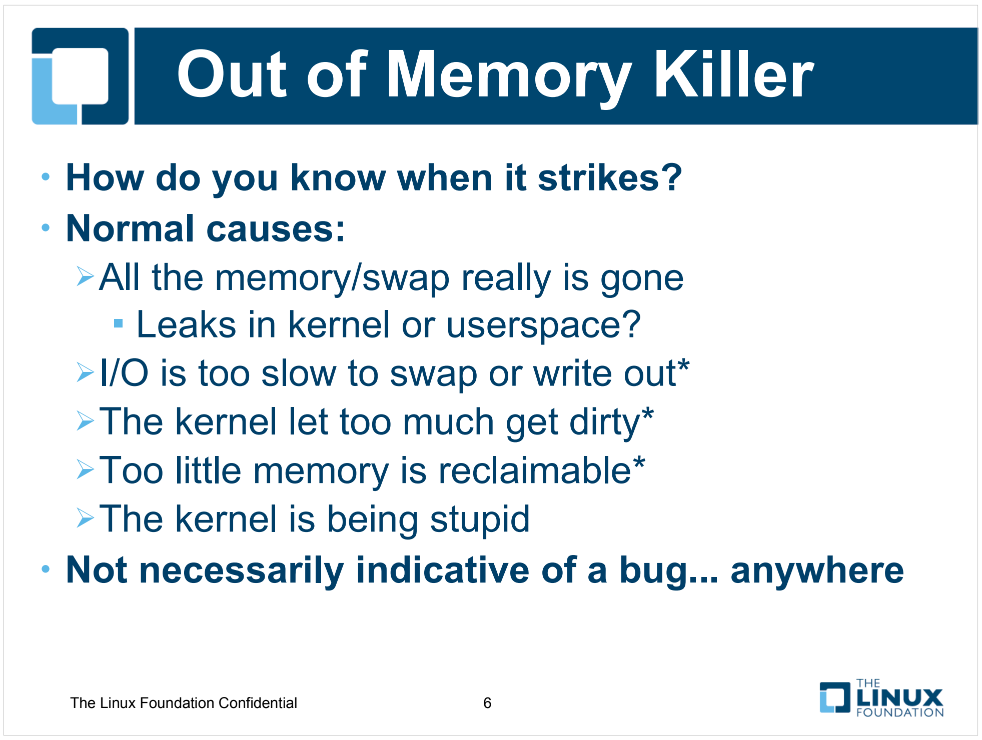

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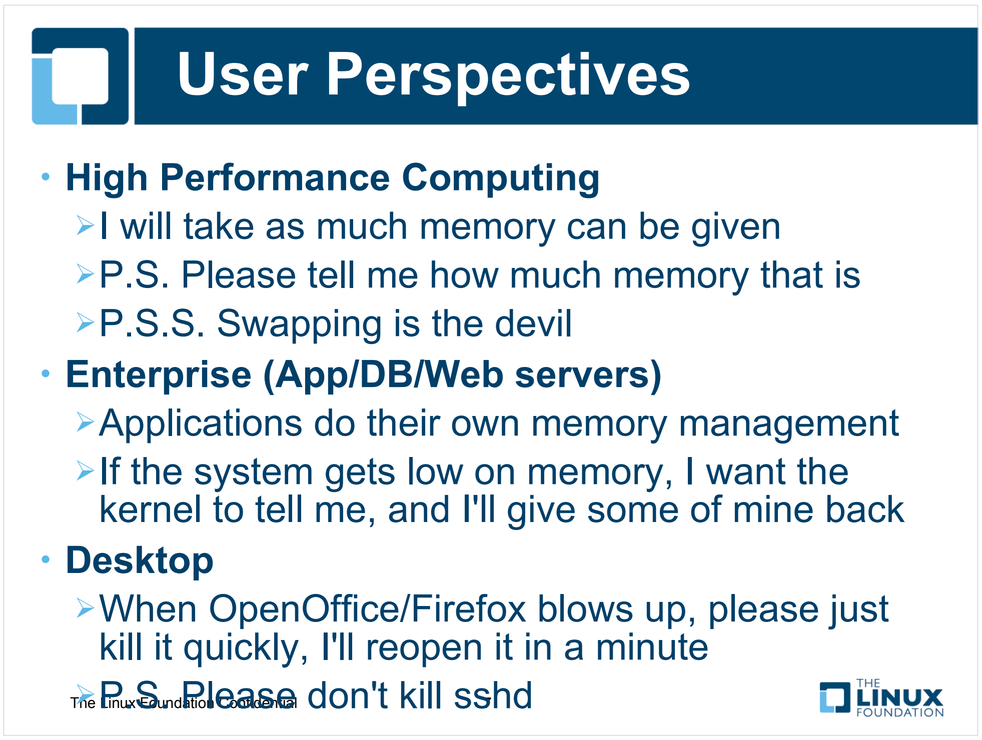

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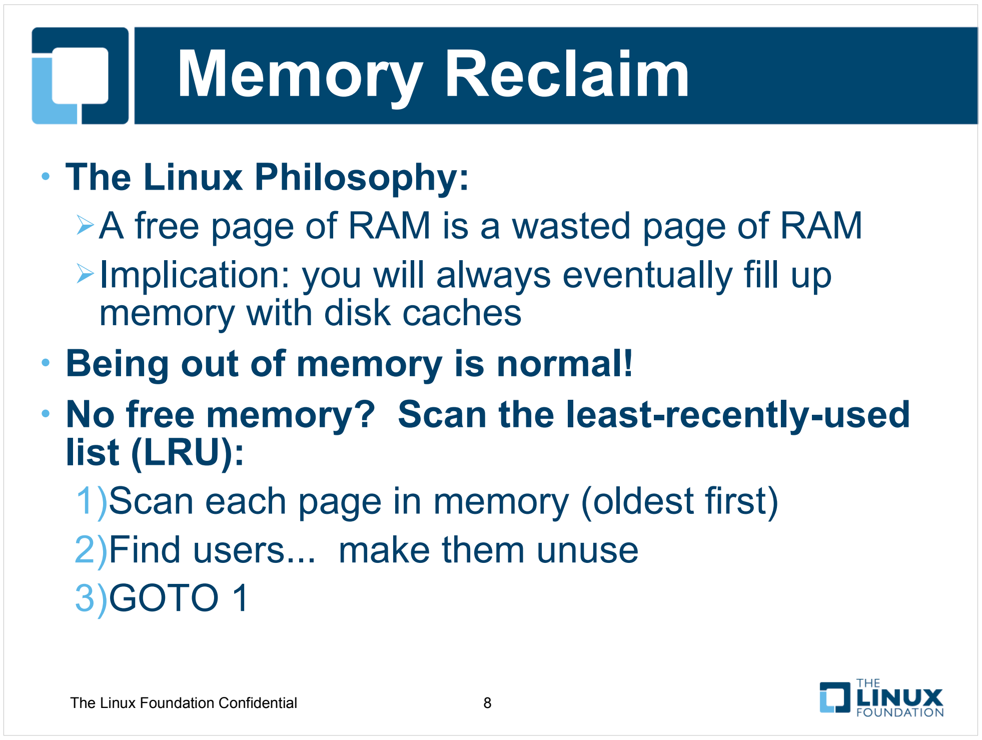

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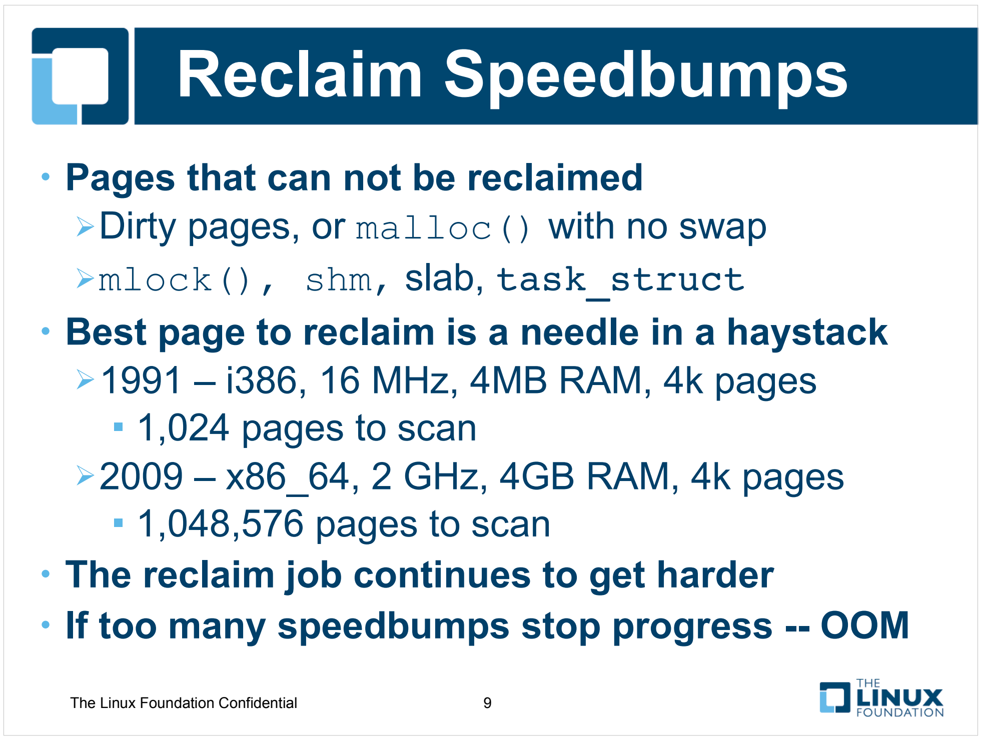

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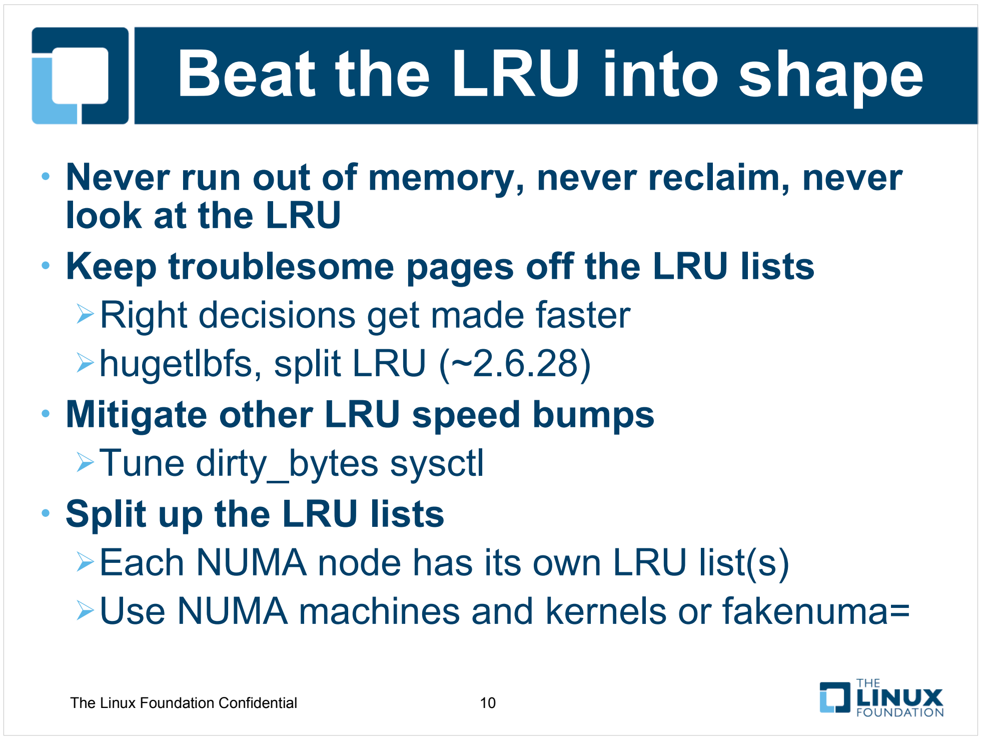
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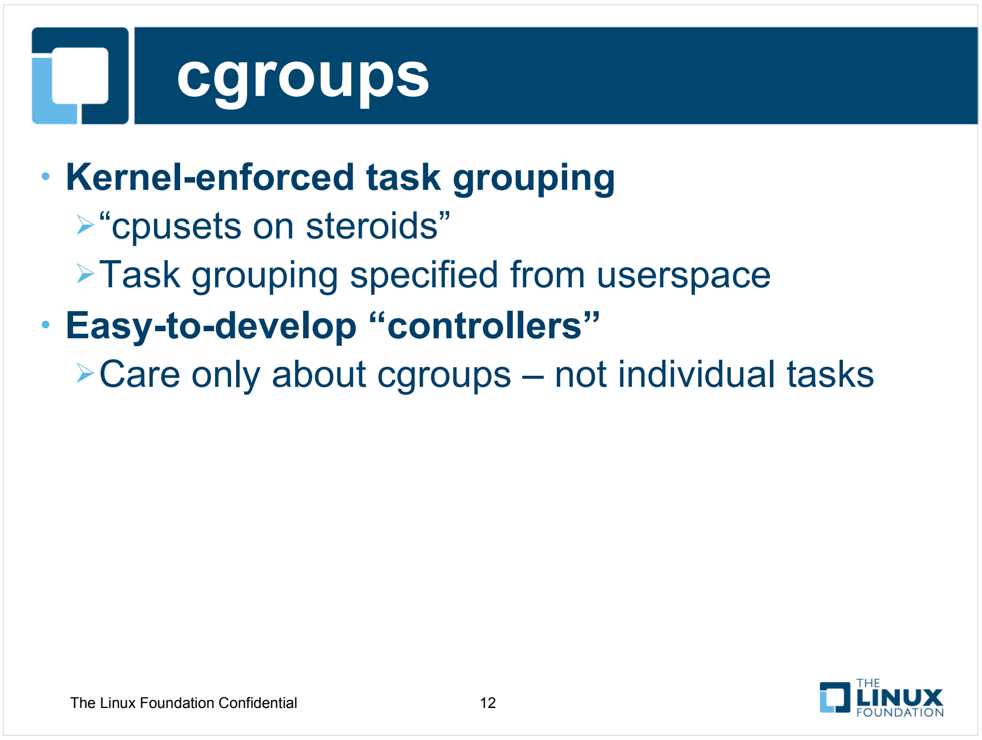

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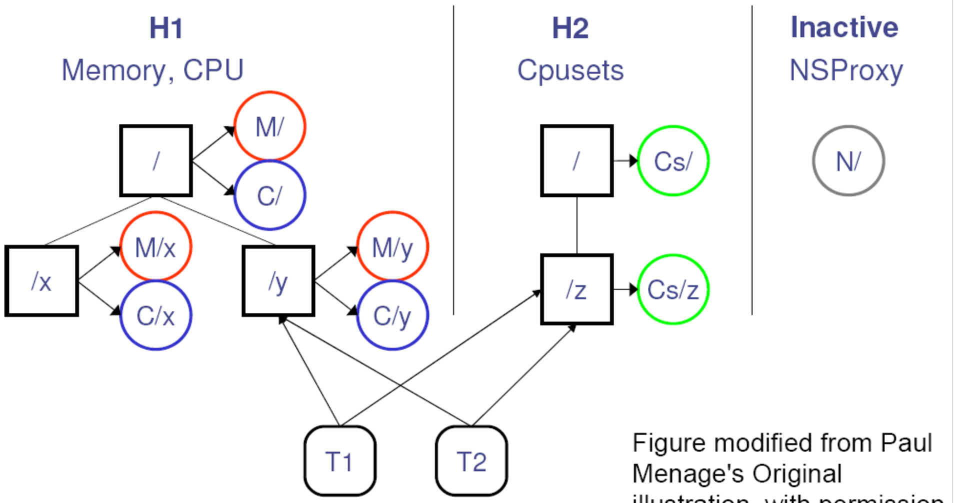

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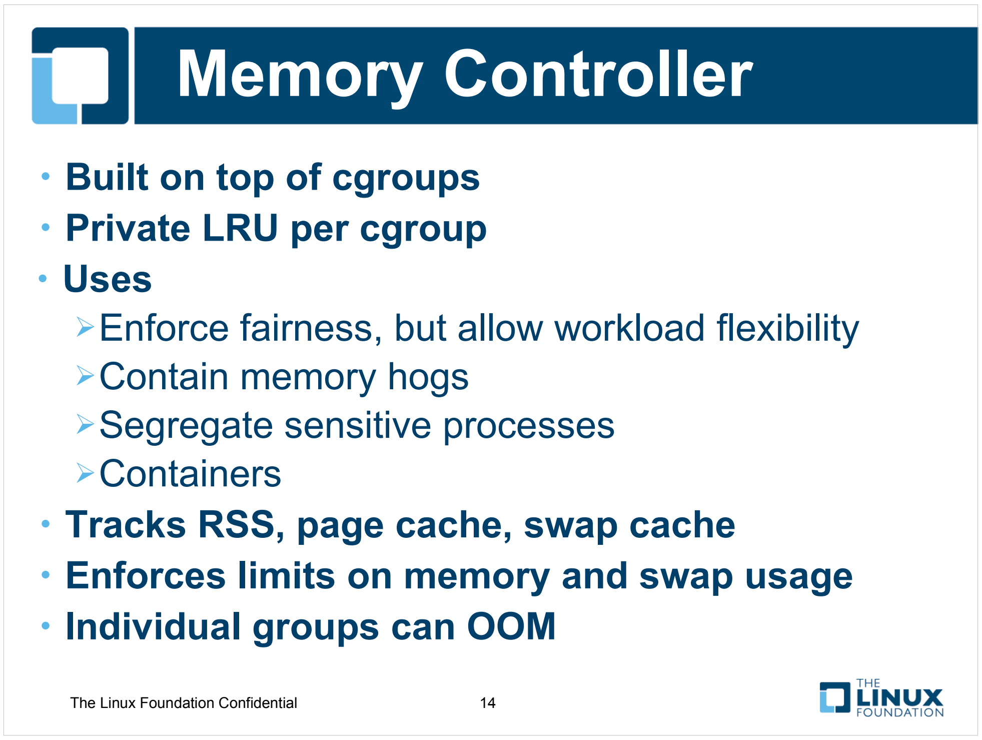

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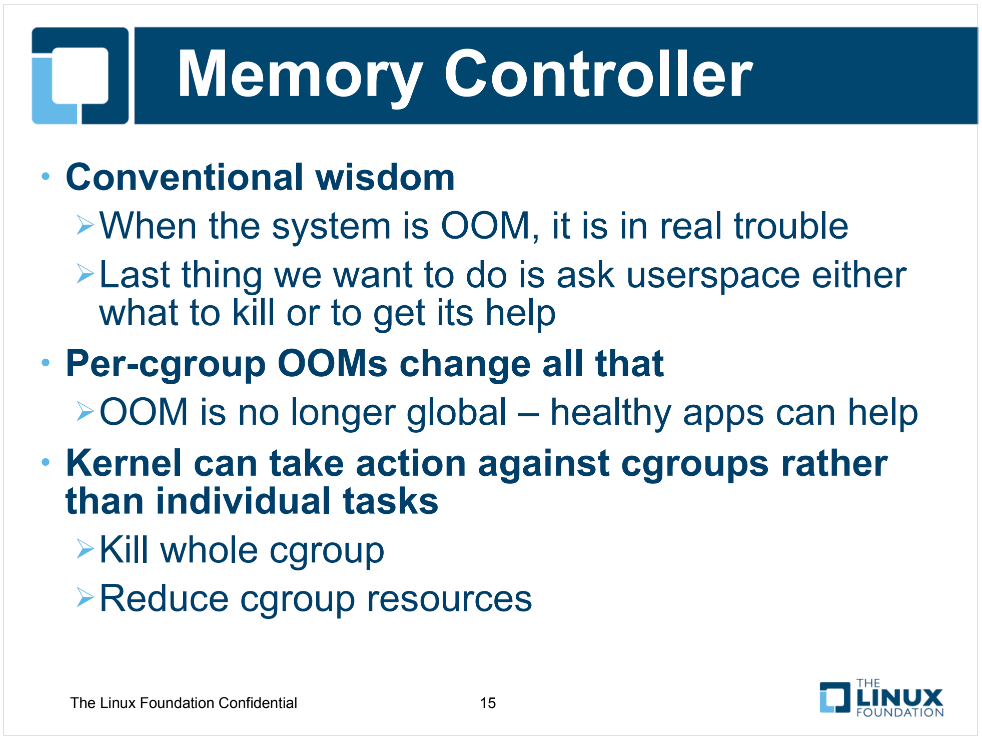

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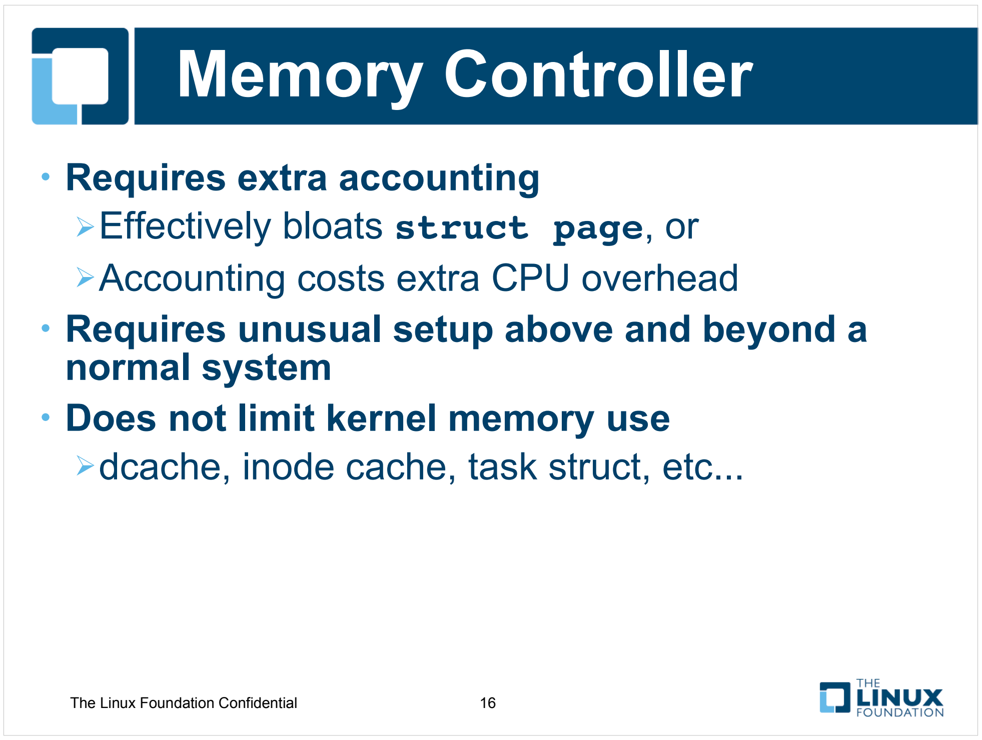

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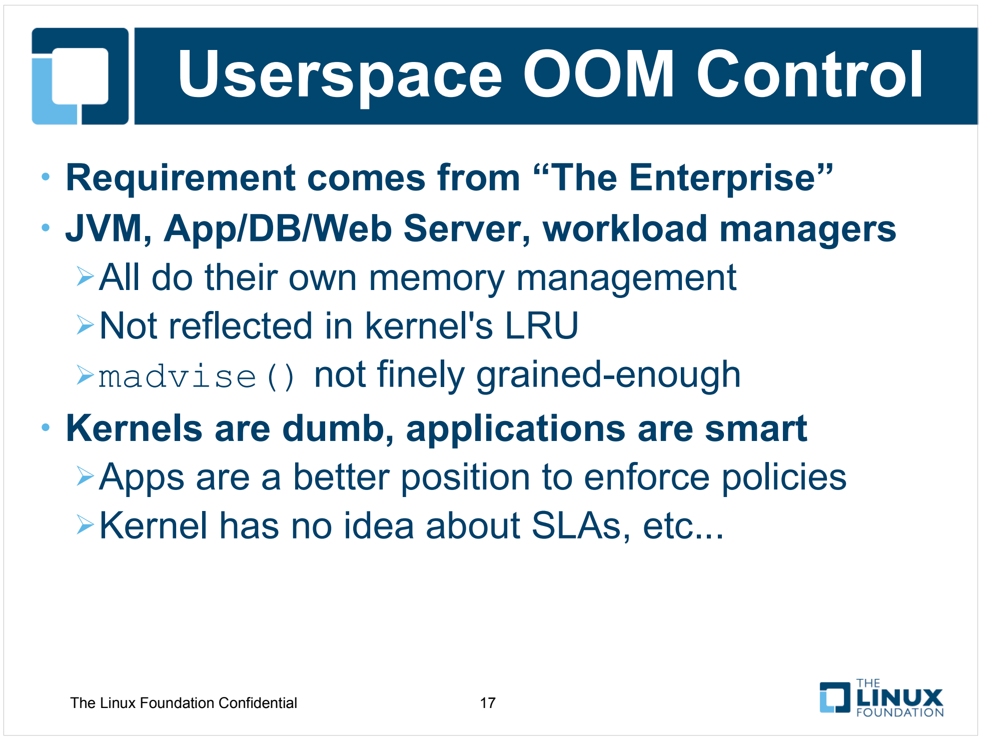

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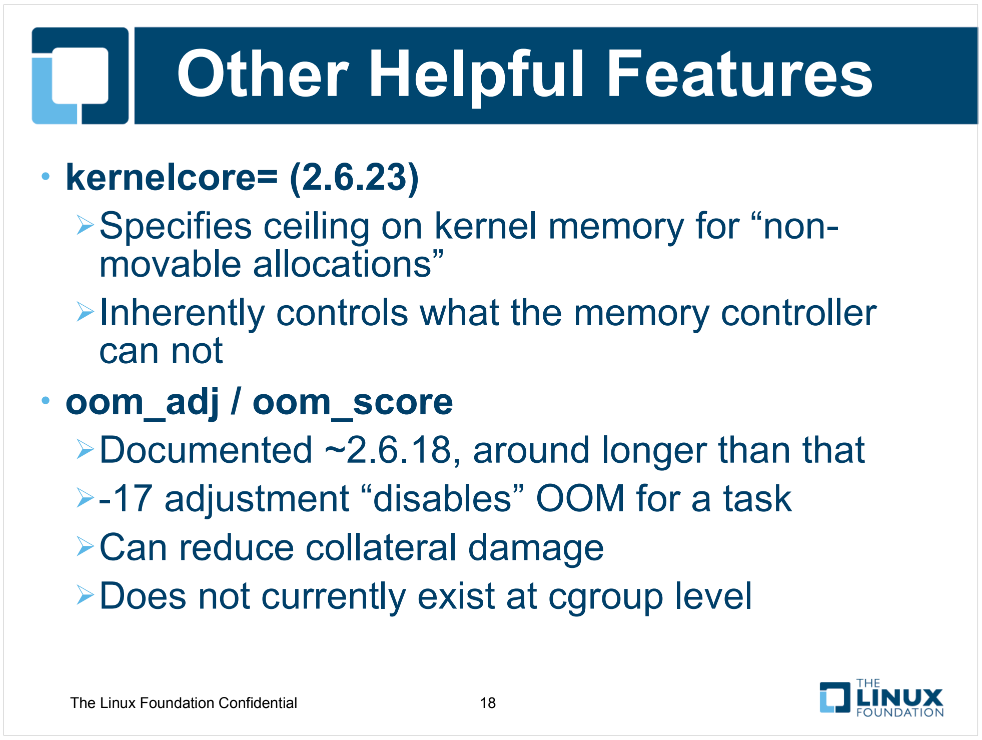

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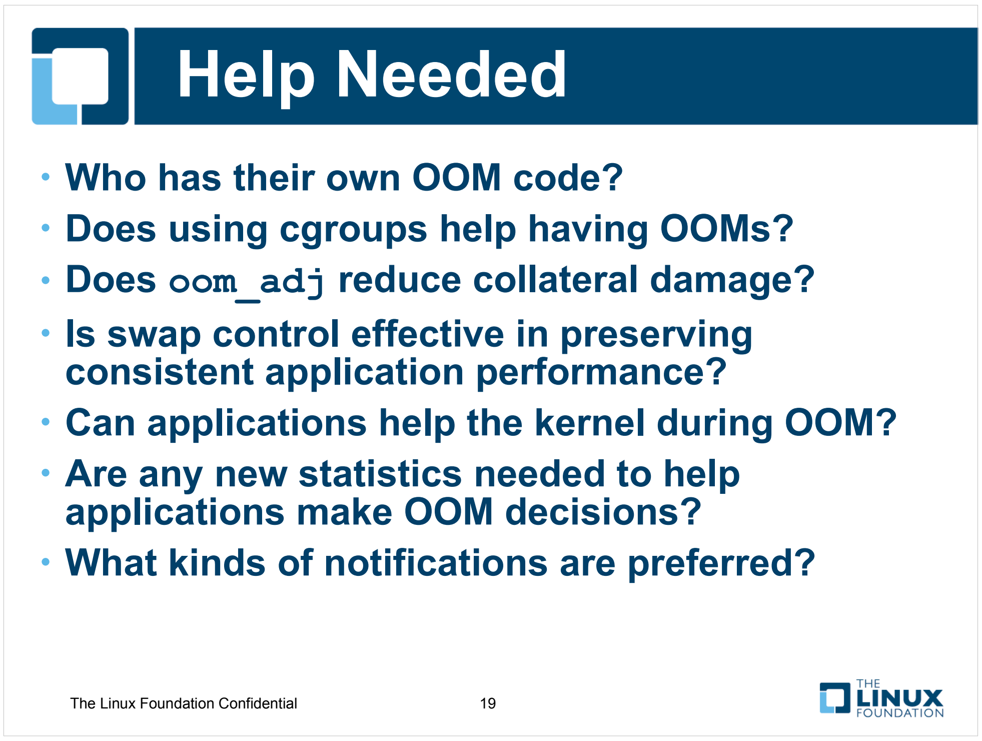

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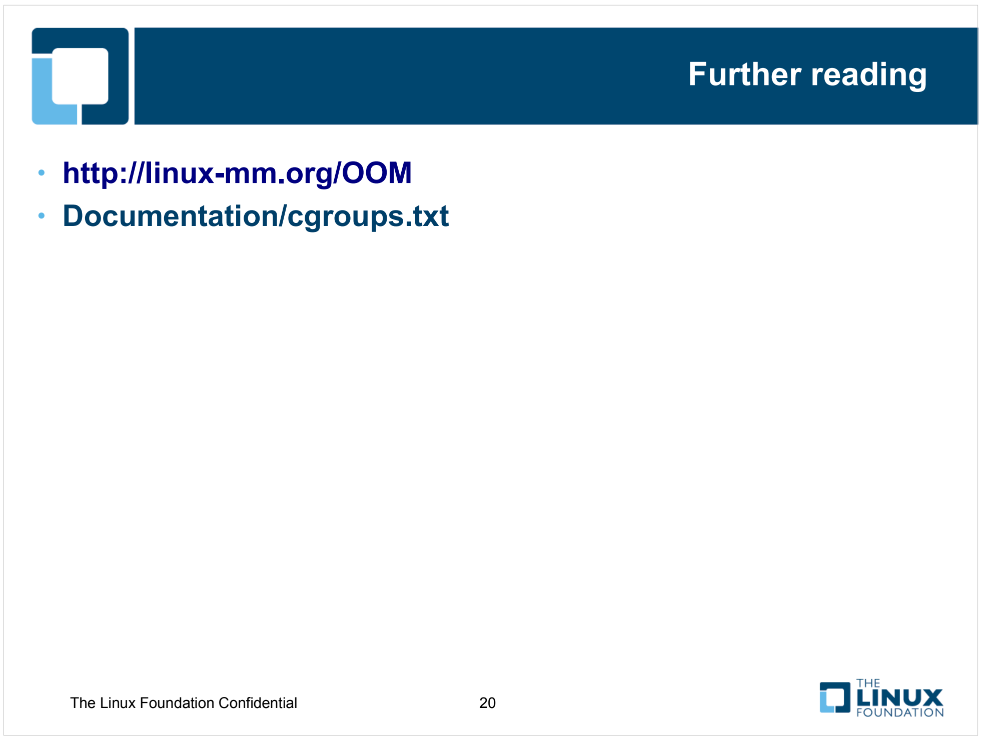

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