

# How To Turn a Penguin Into a Dog

...or...  
Things To Do  
That Will Avoid  
Linux on z Success

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# Goals

- ▶ Examine Linux on z historical roadmap
- ▶ Learn from others' hard-won experiences
- ▶ Understand some things ***not*** to do—and why

BEWARE OF  
ATTACK PENGUIN.

# Linux on z: Ancient History

- ▶ 1999: Linux released for (then) System/390
  - IBM “skunkworks” effort
  - Works, but not a “real” IBM product
- ▶ 2000: “41,000 Linux guests on a VM system”
  - Proof-of-concept, no relation to reality
  - Garnered tremendous press attention
  - Vendors jump in: Linuxcare, Aduva, BMC...

**LINUXCARE**

aduva

bmcsoftware

# Linux on z: Where We've Been

- ▶ 2001–2006: z/Linux growth slow
  - IBM pushes Linux on z hard (IFL loaners, etc.)
  - Many failed pilots, ROI not realized in many cases
  - zSeries CPUs not fast enough to compete with Intel
  - Levanta (Linuxcare), BMC, Aduva(?) quit market
  - Rocket enters with Linux Provisioning Expert (now Mainstar)
  - IBM adds Director for z
  - Computing Solutions Leaders International adds CSL-WAVE
- ▶ **The Dirty Little Secret:**  
*An **untuned** penguin can be a **dog!***
  - But they can be trained, with some tools and effort



# Linux on z: Where We Are

- ▶ 2006–present: z/Linux starts to grow up
  - New, faster processors (z9) made z competitive
  - Nationwide, Wells Fargo, Citi, other “poster children” validate ROI
- ▶ “Now it gets real...”
  - ...and now performance **must** be tamed!



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# Important History

- ▶ Mainframes have been around for a while...
  - z/OS (OS/390, MVS/ESA, MVS/XA, MVS, MVT, MFT): **43 years** (OS/360, 1964)
  - z/VM (VM/ESA, VM/XA, VM/SP, VM/370, CP/67): **43 years** (CP/40, 1964)
  - z/TPF (TPF, ACP): **43 years** (PARS, 1964)
  - z/VSE (VSE/ESA, VSE/SP, DOS/VSE, DOS/VS): the youngster, **42 years** (DOS/360, 1965)
- ▶ We're spoiled by decades of experience
  - We expect that someone, somewhere has done it all

# The New Kid on the Block

- ▶ Linux is just sixteen years old
  - Elderly in penguin years...
  - ...still immature as an OS
- ▶ Only seven years of mainframe Linux
  - Adult in dog or penguin years...
  - Progress made, but many apps still **not** well-behaved!
- ▶ z/Linux tuning and capacity planning still largely unknown territory to many
  - Each new kernel level offers new opportunities (and old opportunities return with kernel changes!)





# Still a Brave New World

▶ **Nobody** really knows all the answers yet

- This is like tuning MVS circa 1980
- ...or maybe more like tuning VM/370 circa 1975

▶ **Not** a reason to avoid Linux!

- Just something to be aware of
- You **cannot** believe everything you hear, good or bad



# Linux Success Requirements

- ▶ Management buy-in and distributed support group support
  - Without both of these, either:
    - Management won't care about success
    - Distributed folks will protect their turf and torpedo you
  - Management can force distributed folks' support
- ▶ Appropriate application choices
  - No fractal reductions, SETI@home
  - Java OK in moderation (many apps are evil, though)
  - VMware has similar constraints (plus no memory overcommitment)



# More Success Requirements

- ▶ A willingness to say “I was wrong”
  - Some applications may turn out to be poor choices
  - Some tuning choices will have the opposite effect
  - **Requires a political climate that lets you say so**
- ▶ Monitoring, tuning, and capacity planning
  - IYDMIYWGS\*
  - Many Linux apps are **not** well-behaved, mature!
  - Must make **correct** tuning choices

\* If You Don't Measure It You Will Get Screwed

# Reasons Linux POCs Fail

- ▶ Lack of management buy-in leading to distributed group non-support
  - “They just didn’t show up for the meetings”
- ▶ Inappropriate application choices
  - “The application we chose just didn’t perform”
  - “Management lost patience”
- ▶ Disappointed by performance
  - Without tools, no way to understand
  - “There is no think, only do” — Master Yoda



# The Real Cause

- ▶ Inappropriate expectations
  - Running thousands of Linuxen on one system
  - “Just port it and it will run”
  - “Mainframes are large and fast”
- ▶ The reality
  - Plan dozens or hundreds of Linuxen per system, **tops**
  - Porting requires understanding, (maybe) rearchitecting
  - Mainframes are **fairly** large and **fairly** fast—now (z10)





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## How To Guarantee Failure

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# Unmeasured Equals Unsuccessful

- ▶ Make unjustified assumptions
  - “Tune it like MVS” (aka “Linux apps are well-behaved”)
  - “The app needs 4GB on Intel, so we’ll give it 4 on z”
  - “More CPUs are good”
  - “Swapping is bad”
  - “z/VM is 64-bit, so we should run 64-bit Linux”
- **Critical requirement: You *must* measure it!**
  - I believed this since long before working at Velocity

# Performance Tuning “Back in the day”

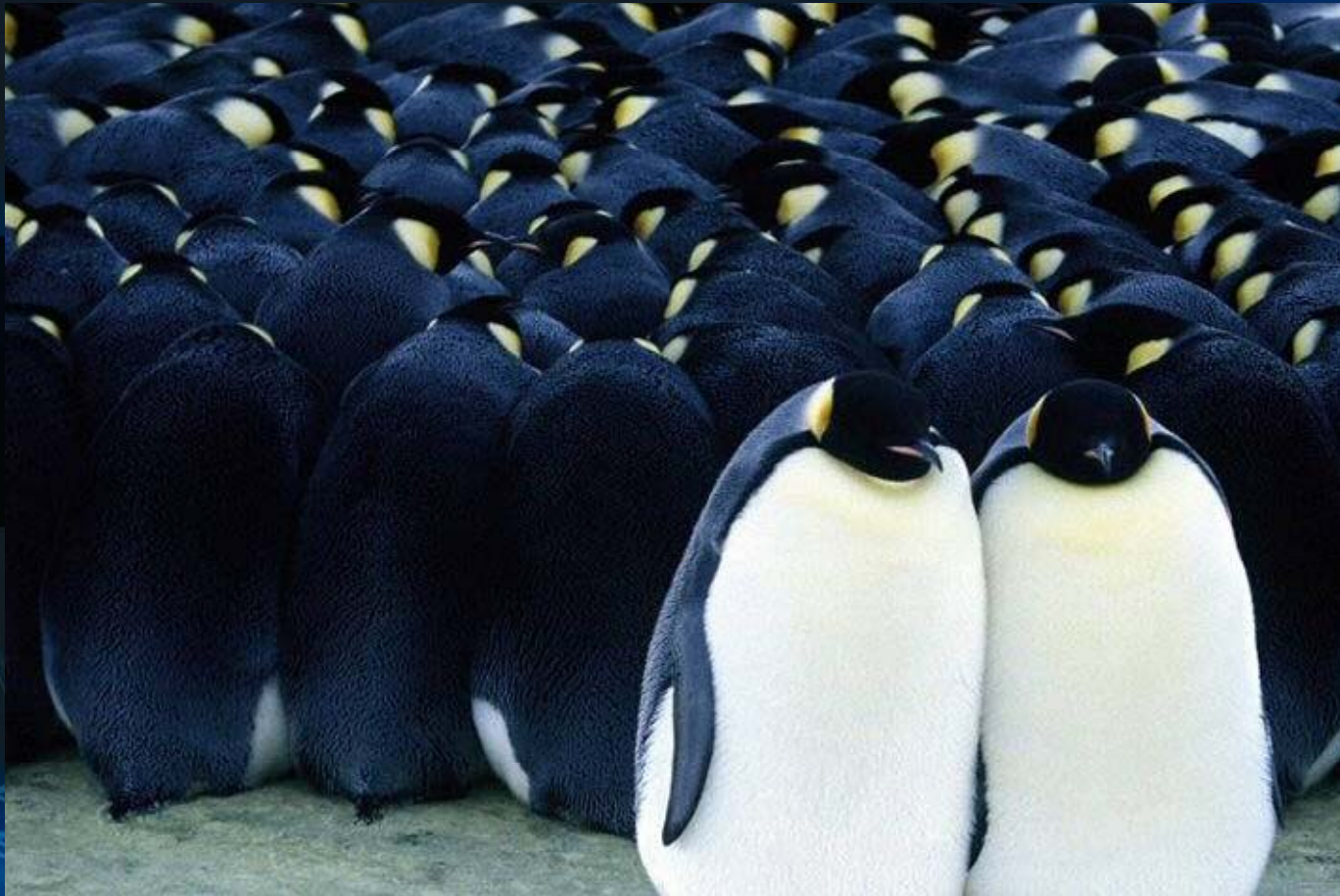
- ▶ VM in days of old
  - Hundreds (or thousands!) of CMS users
  - Relatively small, well-behaved applications
  - Performance degradation was typically gradual
- ▶ Performance tuning was easier **and** harder
  - **Easier**: smaller problems, smaller changes
  - **Harder**: smaller changes, smaller effects



# Why Linux is Different

- ▶ z/VM today
  - Tens (or hundreds) of z/Linux guests
  - Very large, often poorly behaved Linux applications
  - Performance degradation can be precipitous
- ▶ Performance tuning is harder *and* easier
  - **Harder**: bigger problems, bigger changes
  - **Easier**: bigger changes, bigger effects





# Herding Penguins

The single  
most important  
lesson in  
this presentation

(but easier  
than  
herding cats)



# Your Penguins Must Sleep!\*

- ▶ Your idle Linux guests **must** go **truly** idle
  - This is a **memory** (storage) management issue, **not** a CPU usage issue
- ▶ What does “idle” mean?
  - Means “transaction” complete, guest drops from queue
  - CP defines 300ms of idle time = end of transaction
  - Theoretically represents interactive user “think time”
  - Less meaningful for servers, but what better metric?



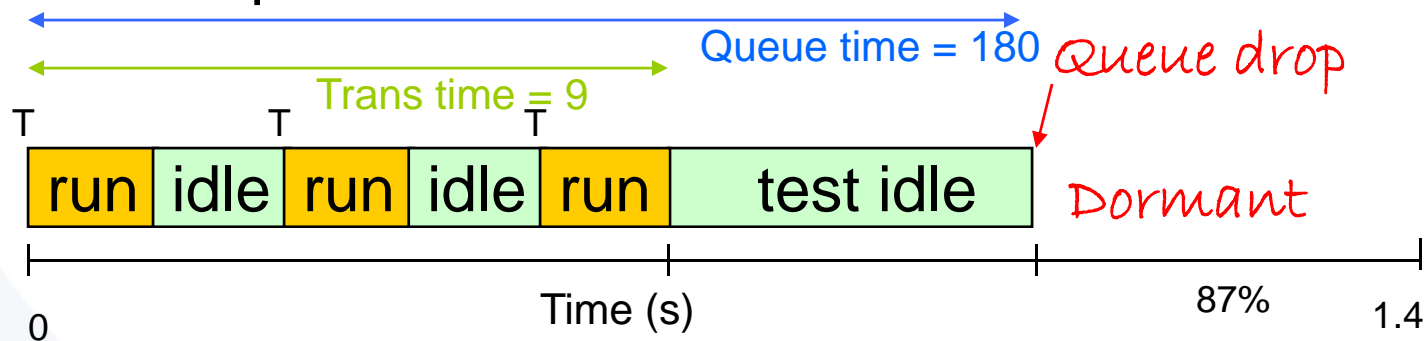
\* Thanks to Rob van der Heij for this line!



# What's a "Transaction"?

- ▶ Anatomy of the average transaction
  - Periods of activity with short idle time between them
  - Starts with a timer interrupt (or perhaps I/O interrupt)
  - Longer idle period at end is followed by queue drop

▶ Example:





# Scheduler and Dispatcher 101

## ▶ Some critical concepts

- Guests must be *runnable* to do work
- CP must be willing to schedule the guest
- CP must be willing to dispatch the guest
- ▶ A guest is always in one of three lists:
  - **Dormant** list: guest has no work to do
  - **Dispatch** list: guest is active, CP is allowing it to run
  - **Eligible** list: guest is active, CP is not allowing it to run
  - (Can also be **running**...special case of Dispatch list!)

# Scheduler and Dispatcher 101

- ▶ **CP scheduler** analyzes resources, decides whether enough to give guest service
  - Entirely storage-related (memory)
  - If not enough available, guests get put on the E-list
- ▶ **CP dispatcher** gives guests access to CPUs
  - If multiple guests are active, they take turns
  - VM is very good at this — supports tens of thousands of active users with excellent response time

# Dispatch Classes – Class 1

- ▶ When first dispatched, guest is Class 1 (“Q1”)
  - CP waits one Class 1 Elapsed Timeslice (C1ETS) to see if it goes idle voluntarily
  - Guests that do not go idle within that timeslice are preemptively stopped from execution— sent back to the scheduler
  - C1ETS is dynamically calculated to keep a fixed % of guests in class 1
  - C1ETS should be enough for short, interactive transactions (minor CMS commands)

## Dispatch Classes – Class 2

- ▶ If guest does not go idle in one C1ETS, it enters Class 2 (“Q2”)
  - Next time CP runs it, given 8x C1ETS
  - Guests that do not go idle within that amount of time are rescheduled
  - Such guests are presumed to be running a command, but not necessarily doing something “major”

## Dispatch Classes – Class 3

- ▶ If guest does not go idle within class 2 C1ETS multiple, it enters Class 3 (“Q3”)
  - Next time CP runs it, given 6x Class 2 = 48x C1ETS
  - Guests that do not go idle within that amount of time are rescheduled
  - Such users are presumed to be running a long-running command

# Dispatch Classes – Class 0

- ▶ **QUICKDSP ON** bypasses some rules
  - Still get rescheduled, but never held in eligible list
- ▶ Interactive guests (on terminals, hitting keys) also get Q0 stays (“hotshot” stays)
  - Still get rescheduled, but “go to head of line” briefly
  - Return to their previous queue level after Q0 stay
  - Virtual machines holding certain short-term system locks are also considered to be in Q0



# Leaving the Dispatch List

- ▶ Guests leave dispatch list because they:
  - Use up their current *CnETS* multiple
  - Go idle voluntarily (load a wait PSW)—see below
- ▶ 300ms **test idle timer** set when guest loads wait PSW
  - Guest resuming activity within that period are reinserted into previous place in queue
  - Guests that don't go idle never get queue dropped!

# How This Plays Out...

- ▶ CP scheduling is based on storage analysis
  - If not enough, guests are held in **Eligible list (E-list)**
  - Assumption: other guests will go idle, storage will become available soon
  - If not, E-listed guests never get scheduled
  - There are actually a host of other bad side-effects of too-large Linux guest virtual storage sizes



# Why This Goes Wrong

- ▶ Linux real storage requirements higher than CMS guests because Linux guests:
  - Are quite large (virtual storage size)
  - Use all storage (working set = virtual storage size)
  - Don't interact with CP to release unused storage
  - Stay active (rarely/never go idle)
- ▶ If enough Linux guests are logged on, CP notices it will overcommit real storage
  - One or more such guests “lose”, are E-listed — and stay there!

# How Does This Manifest?

- ▶ System is running along fine
  - One guest too many is started
  - Things “just stop”!
- ▶ Dispatched guests “should” go idle
  - Linux guests typically don’t, stay runnable all the time
- ▶ Historically, guests doing I/O were “active”
  - Recent releases have mostly eliminated this
- ▶ Remember the test idle timer
  - Guests never go idle (as far as CP can tell)
  - Never get scheduled properly, so E-listing permanent!



# Detection

## ▶ CP INDICATE QUEUES EXPANDED shows:

```
LINUX902      Q3 PS  00013577/00013567  .... -232.0 A00
LINUX901      Q3 PS  00030109/00030099  .... -231.7 A00
VSCS          Q1 R   00000128/00000106  .I.. -208.7 A00
VMLINUX3      Q3 IO  00052962/00051162  .... -.9398 A00
VMLINUX3 MP01 Q3 PS  00000000/00000000  .... .0612 A00
LINUX123      E3 R   00177823/00196608  .... 5255. A00
```

- **HELP INDICATE QUEUES** shows meaning of output
- CP privilege class E required
- **Note:** “deadline time” (sixth column) indicates when CP thinks the guest will run
- Guest **LINUX123** is not running any time soon...

# Remediation

- ▶ Buy lots more storage ( $\$ < 6\text{K/GB}$  — cheap!)
- ▶ Tune applications so guests do queue drop
  - Obviously only meaningful if guests are nominally idle
  - Remember `cron` et al. may wake them anyway
- ▶ Log off some guests
  - You didn't need that WAS application, did you?
- **Tune guest storage sizes**
  - Linux uses “extra” storage for file buffers
  - Smaller guests may actually perform ***better***



# Why Idle Guests are Important

- ▶ CP analyzes storage use when guests go idle
  - Avoids taking pages from active guests
- ▶ Three-pass process
  - First pass analyzes users on dormant list—never happens if Linux guests never go idle!
  - Result: CP must steal pages, makes wrong guesses
  - Causes thrashing—pages go out, come right back in
- ▶ Linux and z/VM paging algorithms collide
  - When Linux wants a page, where does it look? (LRU)
  - Where is that page most likely to be?



# Care and Feeding of Aptenodytes

Keeping  
your penguins  
from  
becoming dogs

# “Jiffies”

- ▶ “Jiffies”: Frequent Linux timer pops
  - Controlled via setting in `/proc`
- ▶ “Correct” setting is perhaps unintuitive
  - 0 is what you want:  
`echo 0 > /proc/sys/kernel/hz_timer`
- ▶ Why do “jiffies” hurt?
  - 10ms is a lot less than the CP idle timer of 300ms
  - Guests with the timer ON never go idle
- ▶ Make sure “jiffies” are off!



# Virtual Multiprocessors

- ▶ Don't use virtual MPs without **good** reason
  - Most Linux applications don't exploit MP
  - Exception: apps that use more than one CPU of MIPS
- ▶ Bogus advice, frequently heard:  
"Define as many vCPUs as real CPUs"
  - Valid **only** in lab, single-Linux-guest environment
- ▶ Note: Linux doesn't report MP usage
  - Harder to prove MP need (or lack thereof)

# Virtual Multiprocessors

- ▶ Why does this hurt?
  - Guest isn't idle until all vCPUs are idle
  - Virtual MP spreads timer events over vCPUs
  - Thus MP = more transactions = more in-queue time
- ▶ Bigger problem: significant CPU wastage
  - Inter-vCPU management isn't free
  - Linux spin locks can use an **entire CPU**
- ▶ Use virtual MP only if proven need

# Extra Services

- ▶ Be careful about `cron` and friends
  - Services such as `cron` wake guests up from idle
  - Obviously necessary in some cases, but examine, understand, and experiment!
- ▶ Understand requirement for every service



# Update Services and Friends

- ▶ Watch for the “thundering herd” phenomenon
  - Things like Red Hat Network tend to wake guests up
  - All your guests waking up at once is **not** a good thing!
- ▶ Examine, understand, stagger wakeups
- ▶ Avoid/aggregate services such as updates
  - Why check for updates on **every** guest?
- ▶ Use a single update server!



# 64-bit Linux

- ▶ z/VM no longer runs on 31-bit hardware
  - 31-bit guests still supported, but...
- ▶ Natural assumption: 64-bit guests “better”
  - 64-bit guests require significantly more resources
  - Page tables alone are twice as large (16MB per GB)
  - Other control structures can also be significant
- ▶ Use 64-bit guests only when > 2G virtual memory or specific application requirement

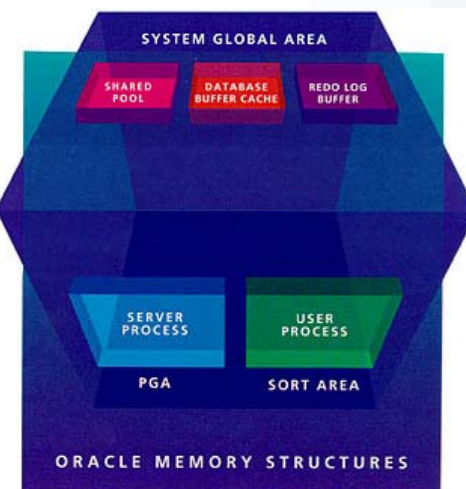
# Swapping and VDISK

- ▶ Intel boxes have fast CPU, RAM; slow disk
  - Conventional wisdom: “Swapping is bad”
- ▶ Swapping to DASD is slow
  - **But** z/VM has VDISK (virtual disk in storage)
  - “Minidisks” that exist in z/VM paging subsystem
- ▶ z/VM paging subsystem is pretty darned fast
  - Conventional wisdom thus **mostly wrong** under z/VM
- ▶ Swapping to VDISK is **way** fast
  - Linux still does I/O, but CP intercepts and handles
  - CP can manage VDISK better (LRU problem again)

# Swapping and VDISK

- ▶ Most applications can stand to swap some
  - Exception: Oracle Shared Global Area (SGA) **must** stay in-memory for reasonable performance
  - Other exceptions surely exist
- ▶ Use small virtual storage + Swap to DASD to slow down guest that's too fast ;-)

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# VDISK Myths and Realities

- ▶ Fear: “VDISK will use too much real storage”
  - Reality: VDISK lives in VM paging subsystem
  - Linux virtual storage lives in VM paging subsystem
  - Real storage use not really affected
- ▶ Reality: VM does better managing both
  - Use smaller Linux virtual storage + VDISK for swap
  - VM controls both, rather than Linux caching data, causing VM paging through LRU mismatch
- ▶ Myth: “VDISK pages never migrate to DASD”
  - Fact: CP Monitor records prove otherwise

# VDISK Notes and Recommendation

- ▶ VDISK notes:
  - Max size: 2G-1 page (4194296 512-byte blocks)
  - Control via CP `SET VDISK` command (privileged)
- ▶ Use **two** VDISKs, prioritized
  - Linux “moving cursor” algorithm wanders across disk
  - With one, large VDISK, entire disk winds up “dirty”
  - With two, Linux will use higher priority first
  - Avoids old, “dirty” pages lingering in VM paging space
  - Note: “higher priority” is numeric — 10 is higher than 1 (unlike your tasks at work!)



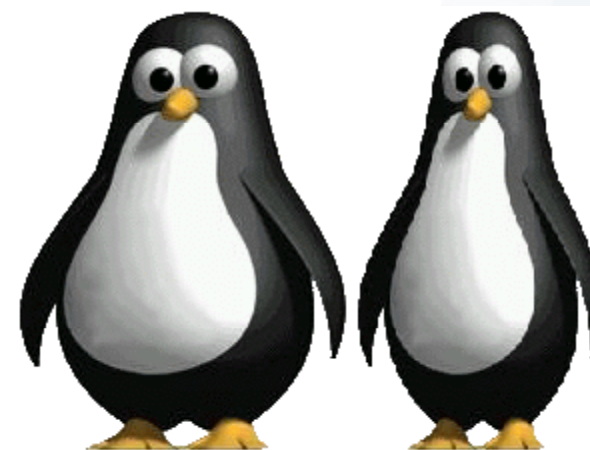
# Large Virtual Storage (Memory)

- ▶ Example: 256MB virtual storage vs. 1024MB
  - 8MB more real storage required just for page tables
  - 16MB if 64-bit guest!
  - Significant even if not actually **using** the storage!
- ▶ Recommendation: Tune virtual storage size
  - “Squeeze until it hurts”
  - Then give it a bit more (or not — let it Swap, to VDISK)

*Penny Craig*<sup>®</sup>

Before

After



# Virtual Storage and Linux Caching

- ▶ Linux caches data (read *and* write)
  - Data may be replicated five times:
    1. Linux file buffers
    2. z/VM minidisk cache/paging subsystem
    3. Controller cache
    4. Device cache
    5. “Brown, round, & spinning”
- ▶ Multiply cached data probably not helpful!
  - Tuning virtual storage size controls this

# Minidisk Cache

- ▶ Minidisk cache (MDC) is a powerful tool
  - But only for data that actually gets reread
  - And not if the data is cached by Linux too...
- ▶ Default: MDC uses both main and XSTORE
  - CP “Arbiter” that controls XSTORE use seems broken
  - MDC can use huge amounts of XSTORE for no gain
  - Even decent MDC hit ratio may not justify increased paging load due to reduced main/XSTORE available
- ▶ **CP SET MDCACHE XSTORE 0M 0M**

# QUICKDSP ON

- ▶ CP SET QUICKDSP ON *sounds* good
  - “This guest is important, we want it to run fast!”
- ▶ Reality: makes guest avoid scheduler, *not* “run faster”
  - Circumvents scheduler “smarts”
  - Result: when storage overcommitted, CP thrashes
  - Result: worse performance for everyone
- ▶ Use QUICKDSP only by prescription\*

\* And for MAINT, when you’re doing performance tuning...!

# SHAREs

- ▶ ABSOLUTE SHAREs **sound** good
  - “We can ensure that this machine gets xx% of a CPU!”
- ▶ Reality: Difficult to manage with many guests
  - With one or two, quite feasible—but at that point, RELATIVE SHAREs work just as well
  - Use ABSOLUTE for TCPIP et al (machines others depend on) to ensure service even when system busy
  - Note ABSOLUTE SHAREs are % of **entire system**
- ▶ Leave SHARE at **RELATIVE 100** unless addressing **specific** performance problem

# SRM

- ▶ CP SRM settings provide some system performance management “knobs”
  - Be careful: These are **big** knobs
    - **Misapplied, they *will hurt!***
- ▶ Default SRM settings based on CMS users
  - Most are still OK for z/Linux
  - Be careful of “lore” suggesting changes unsupported by measured results



# SRM LDUBUF

- ▶ Some “lore” suggests raising **SRM LDUBUF** is a good idea
  - Actual measured results suggest otherwise
  - Controls the number of “loading” users (users with significant paging activity) allowed in-queue
- ▶ **Never never increase this with z/Linux!**
  - In large shops, may actually want to **lower** it
  - E.g., 50 page packs on 8 CHPIDs—CP probably can’t really support that many loading users

# SRM STORBUF and XSTOR

- ▶ **STORBUF** controls CP's storage usage calculations by queue
  - Linux guests are always Q3, so default incorrect
  - Best to essentially disable its function
  - Default: `SET SRM STORBUF 125 95 75`
  - Suggest: `SET SRM STORBUF 300 300 300`
- ▶ Also: `SET SRM XSTORE 50%`
  - Includes 50% of expanded storage in calculations
- ▶ **Measure** results on your system!

# z/VM 5.2 and 5.3

- ▶ IBM has done **tons** of work to make z/VM a better host for Linux
  - Example: fixes allow queue drop when I/O outstanding
- ▶ z/VM 5.2/5.3 continue the tradition
  - Many small enhancements that make Linux run better
  - z/VM upgrades aren't a big deal any more
- ▶ If you aren't on 5.2 or 5.3, get there ASAP!
  - 5.3 is best choice

# CMM

- ▶ CMM: Collaborative Memory Management\*
  - Allows dynamic Linux storage tuning
- ▶ Driver from IBM Böblingen
  - Accepts commands via CP `smsg`, allocates storage within Linux, tells CP “fuhgeddaboutit”
  - CP no longer has to manage those pages
- ▶ Lets you “inflate a balloon” within Linux
  - Linux continues operation, working set greatly reduced
  - If swapping becomes a problem, release some pages!

\* Or possibly “Cooperative Memory Management” — nobody seems to be sure!

# CMM In Action

## ▶ Linux without CMM

4GB  
virtual  
storage

## ▶ Linux with CMM

4GB  
virtual  
storage  
minus  $nn$   
pages

Linux still *thinks* it has 4GB

“Rest” of storage *not managed by VM*

Multiply savings by  $n$  guests...

# CMM Benefits

- ▶ CMM avoids most of the complaints about storage tuning
  - “We don’t want to reboot”
  - “This isn’t peak load, and we can’t reboot when it is!”
- ▶ Critical for Linux success in some shops
  - Real example: Oracle said “App needs 4GB”; Linuxen have 4GB, but only 1GB *really* available!
  - Apps folks still *think* they have 4GB
  - Without CMM,  $n \times 4\text{GB} = \$\$\$$  for more real storage (or unacceptable performance)



# CMM2

- ▶ z9 added hardware support for “CMM2”
  - Cooperative z/VM–z/Linux page management
  - Intended to reduce double paging, LRU thrashing
- ▶ Adds **CP SET** and **QUERY MEMASSIST**
  - Requires z/VM 5.2 with PTFs UM31784, UM31868
  - SLES 10 SP1 supports via `cmma=on` IPL option
  - No support in RHEL4 or RHEL5 (yet?)
- ▶ No proven success in the field
  - Stick with CMM(1) for now

# XIP

- ▶ XIP = eXecute-In-Place
  - DCSSs under Linux, containing stored, shared data
  - Manifest as special filesystem type
- ▶ Use XIP when possible to share static data
  - Common applications can save significant real storage
  - Requires some management and care
  - Evolving area, stay tuned!
- ▶ Explore for common apps (SNMP, etc.)

# Summary



(C) ON-NO.NET

# Summary

- ▶ Linux on System z is reaching adolescence
  - Much progress made, lots more to do
- ▶ Tuning Linux on z is an emerging science
  - We're still learning, and it's a moving target
- ▶ As always, use the community
  - z/Linux mailing list: `LINUX-390@marist.edu`
  - z/VM mailing list: `IBMV@listserv.uark.edu`
- **Measure, test, prove — don't rely on rumor, innuendo, and lore!**

# Questions?



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## Thanks to

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