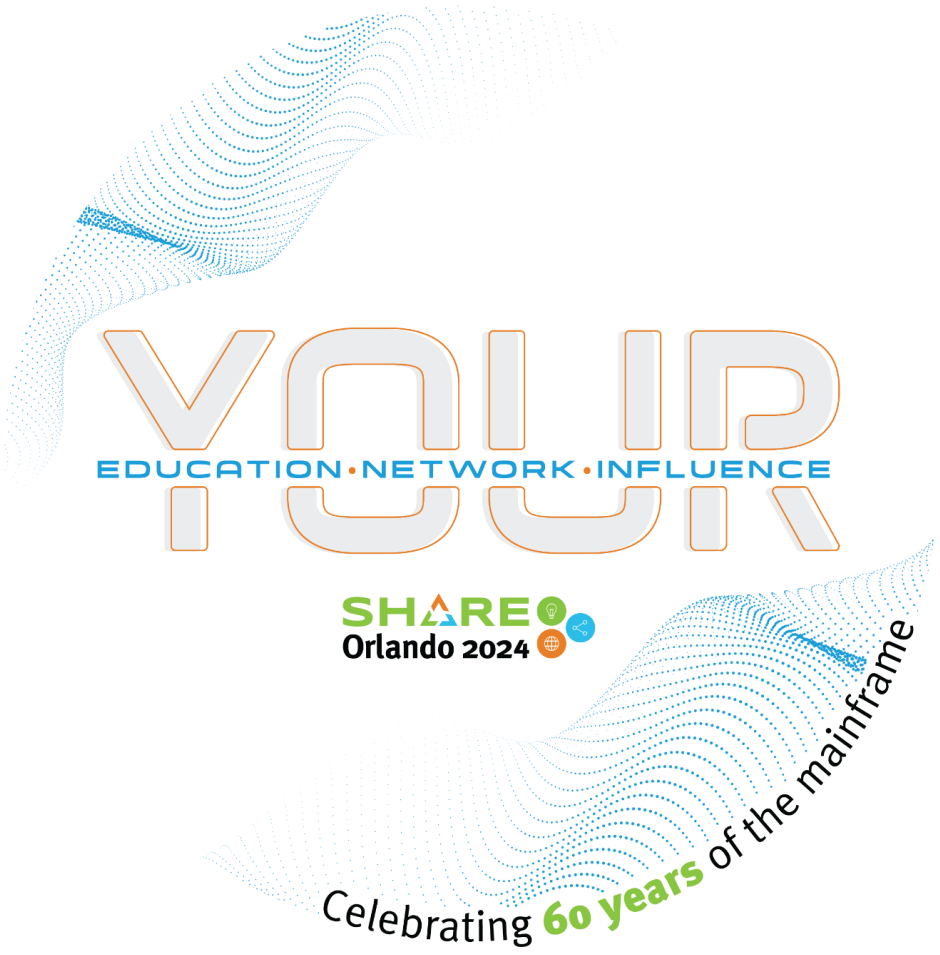

CPU Critical: A Modern Revisit of a Classic WLM Option

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EPS presentations this week

What	Who	When	Where
CPU Critical: A modern revisit of a classic WLM option	Peter Enrico Scott Chapman	Mon 4:00	Salon 12
30th Anniversary of Parallel Sysplex: A Retrospective and Lessons Learned	Peter Enrico	Tue 10:30	Salon 21
z/OS Performance Spotlight: Some Top Things You May Not Know	Peter Enrico Scott Chapman	Tue 1:00	Salon 15
The Highs and Lows: How Does HyperDispatch Really Impact CPU Efficiency?	Scott Chapman	Thu 10:30	Salon 21
Configuring LPARs to Optimize Performance	Scott Chapman	Thu 2:30	Salon 21

Presentation Overview

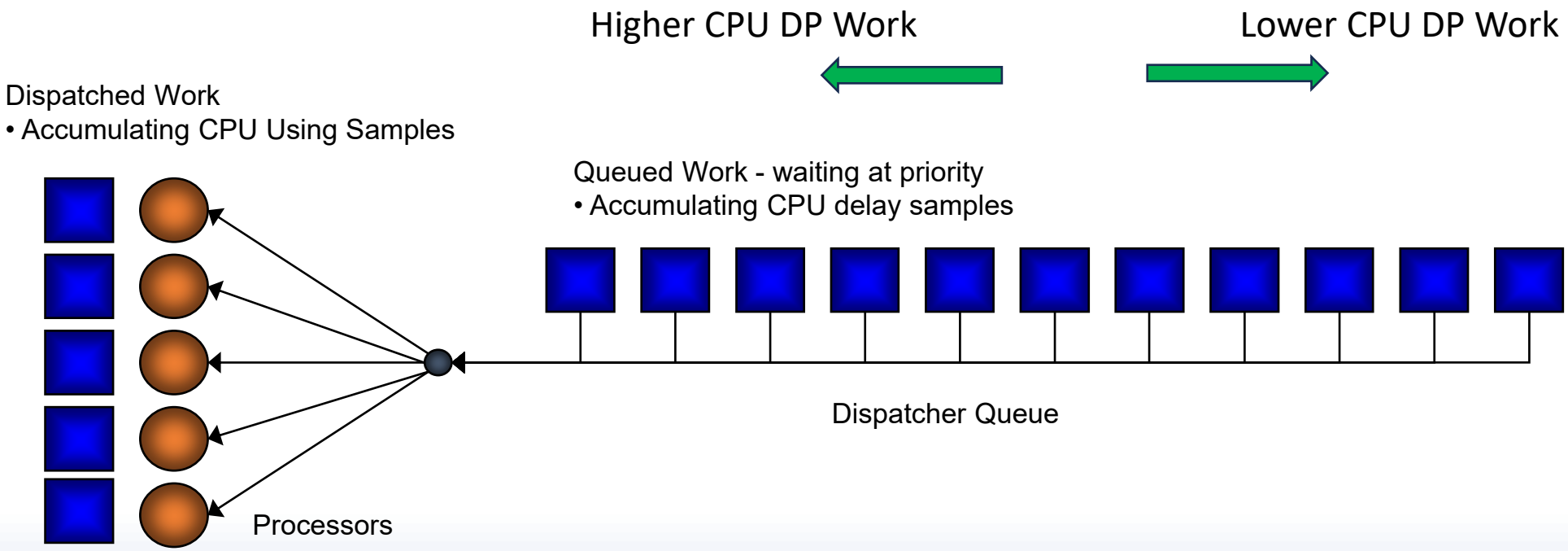
- z/OS 3.1 is defaulting all importance 1 workloads to “Implicit Long-Term CPU Protection”, aka “CPU Critical”
  - This will likely lead to dispatching priority changes on most systems.
  - Some environments will be significantly impacted

- This presentation
  - Refresher of z/OS CPU Dispatching and Dispatching Priorities
  - Refresher of WLM CPU controls and algorithms
  - Refresher of CPU Critical Control
  - Overview of new Implicit CPU Protection in z/OS 3.1

Refresher : CPU Dispatching and Dispatching Priorities

Defining CPU Dispatching Priorities

- Dispatching priorities determine the order in which operations are executed by the CPU
  - All address spaces and enclaves are assigned a CPU dispatching priority
  - The dispatching priority order is determined by WLM based on WLM goals
  - Work queued to use the CPU is placed onto the dispatching queue in CPU dispatching priority order



CPU Dispatching Priorities Schema

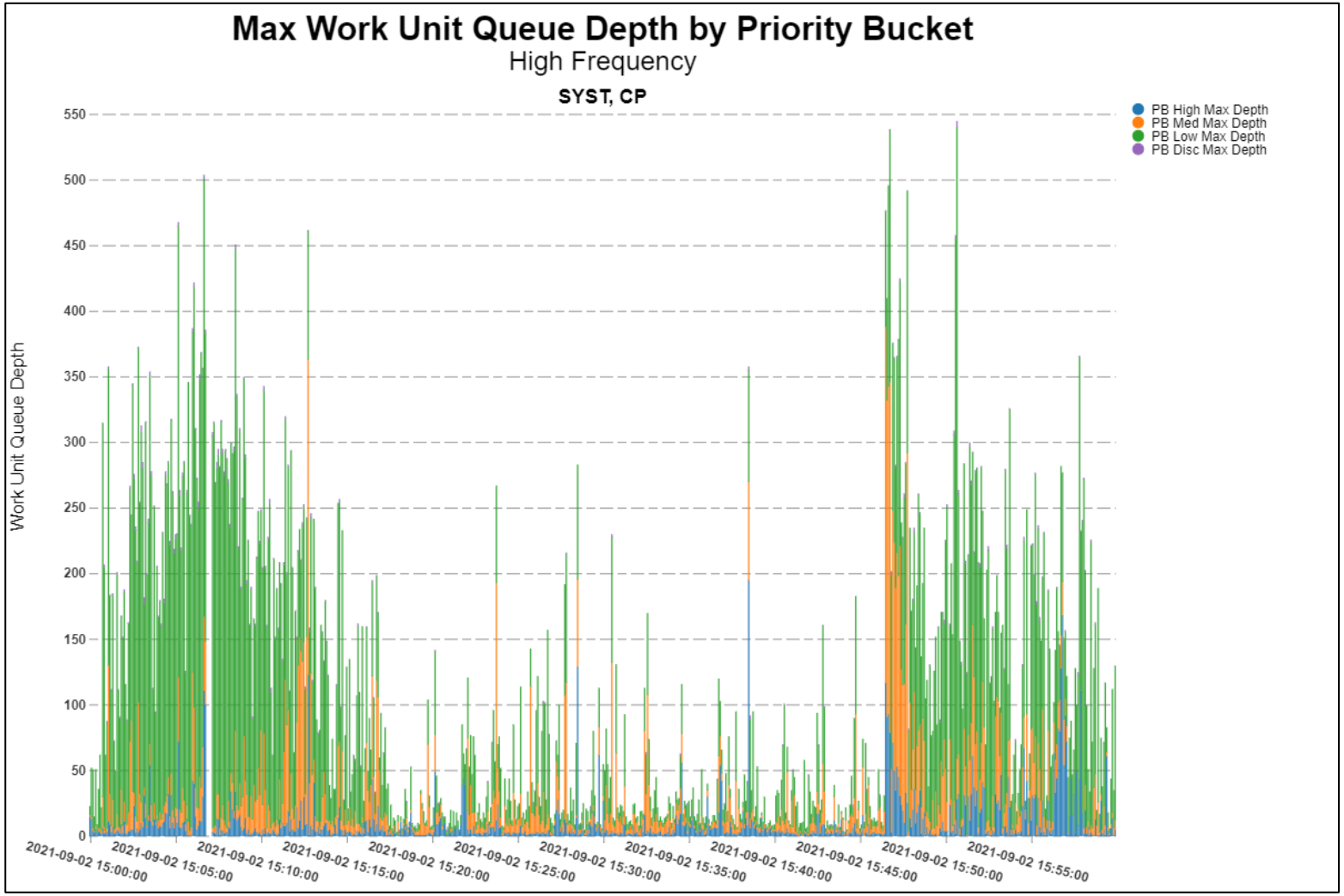
- The reasons we care about CPU DP order
  - Prioritization of CPU access to each workload
  - To assist when there are feeder effects
  - Workload efficiencies
  - Managing goals and processor optimization by addressing processor delays
- Other reasons include
  - CPU promotion for work holding a resource
  - Reduced preemption
  - Fairshare dispatching

255	SYSTEM
254	SYSSTC
253 249	Unused
248	Small Consumer
247 203	Priorities Used for RT or Velocity Periods (i.e. Imp 1 – 5)
202	Unused
201 192	Discretionary (MTTW)
191	Quiesce

Reason 1: Why we care about CPU DPs

- Reason 1: Prioritization of CPU access to each workload
  - Example: Higher importance work should run at higher CPU DPs
- Although not a hard and fast rule, to meet goals, higher importance work tends to receive higher CPU DPs from lower importance work
- Relative importance does not translate to relative CPU DPs
  - A higher importance goal could have a lower CPU dispatch priority than a lower importance goal
  - CPU Critical control does influence this
    - Says lower importance work will never have same or higher DP as work identified as CPU critical

Use SMF 98 to look at dispatch queue depths



Priority bucket statistics

(1=High, 2=Med, 3=Low, 4=Discretionary)

This chart is related to the previous chart, but for CP engines rather than zIIP engines.

We see that although the dispatching queues are longer. The displaceable work is lower importance. Thus, crossover of higher importance will displace this lower importance work.

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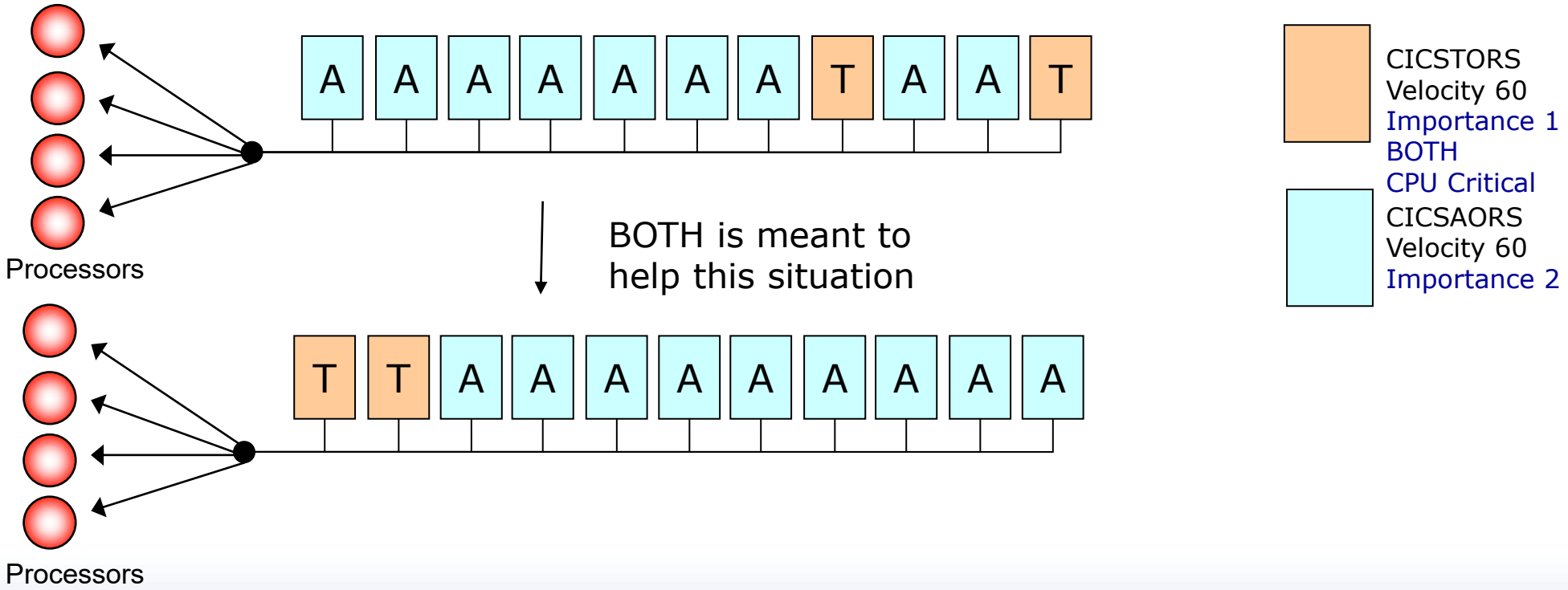
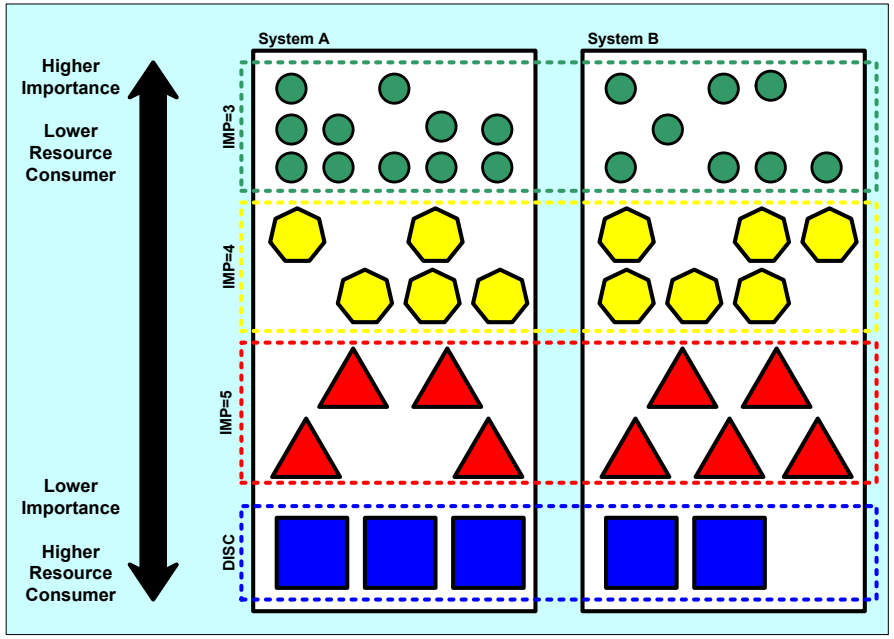
Reason 2: Why we care about CPU DPs

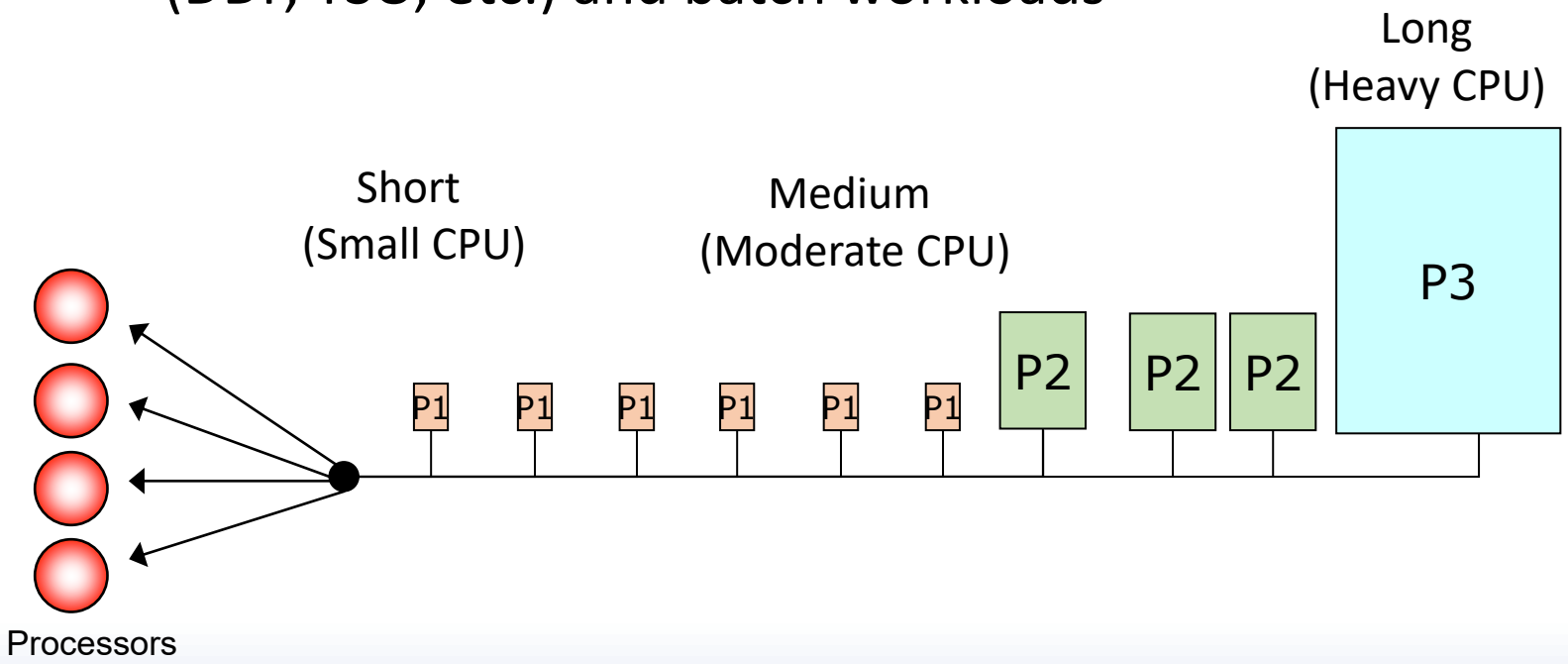
- Reason 2: To assist when there are feeder effects
  - Example: Certain workloads feed other workloads to progress work
  - IRLM -> DB2 (DBM1,MSTR,DIST) -> CICS TOR -> CICS AOR



Reason 3: Why we care about CPU DPs



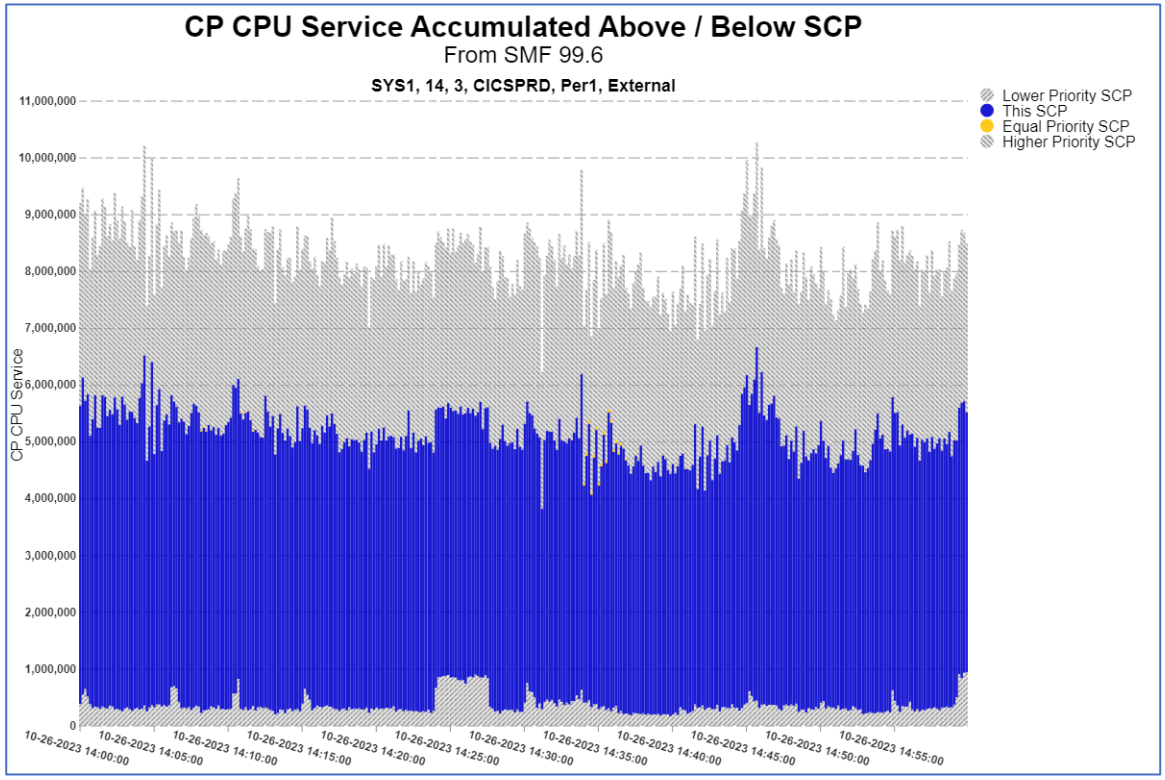
- Reason 3: Workload efficiencies
  - Example: Get the shorter work (light CPU consuming work) on the CPU first to get it 'in and out' as quickly as possible
  - This is extraordinarily effective with interactive (DDF, TSO, etc.) and batch workloads



Reason 4: Why we care about CPU DPs

- Reason 4: Managing goals and optimize processors by addressing processor delays
  - Helps address latent demand
  - Correct CPU dispatching priority helps manage and alleviate latent demand and processor delays
  - Example: Over initiation of batch, many more CICS regions than number of CPUs

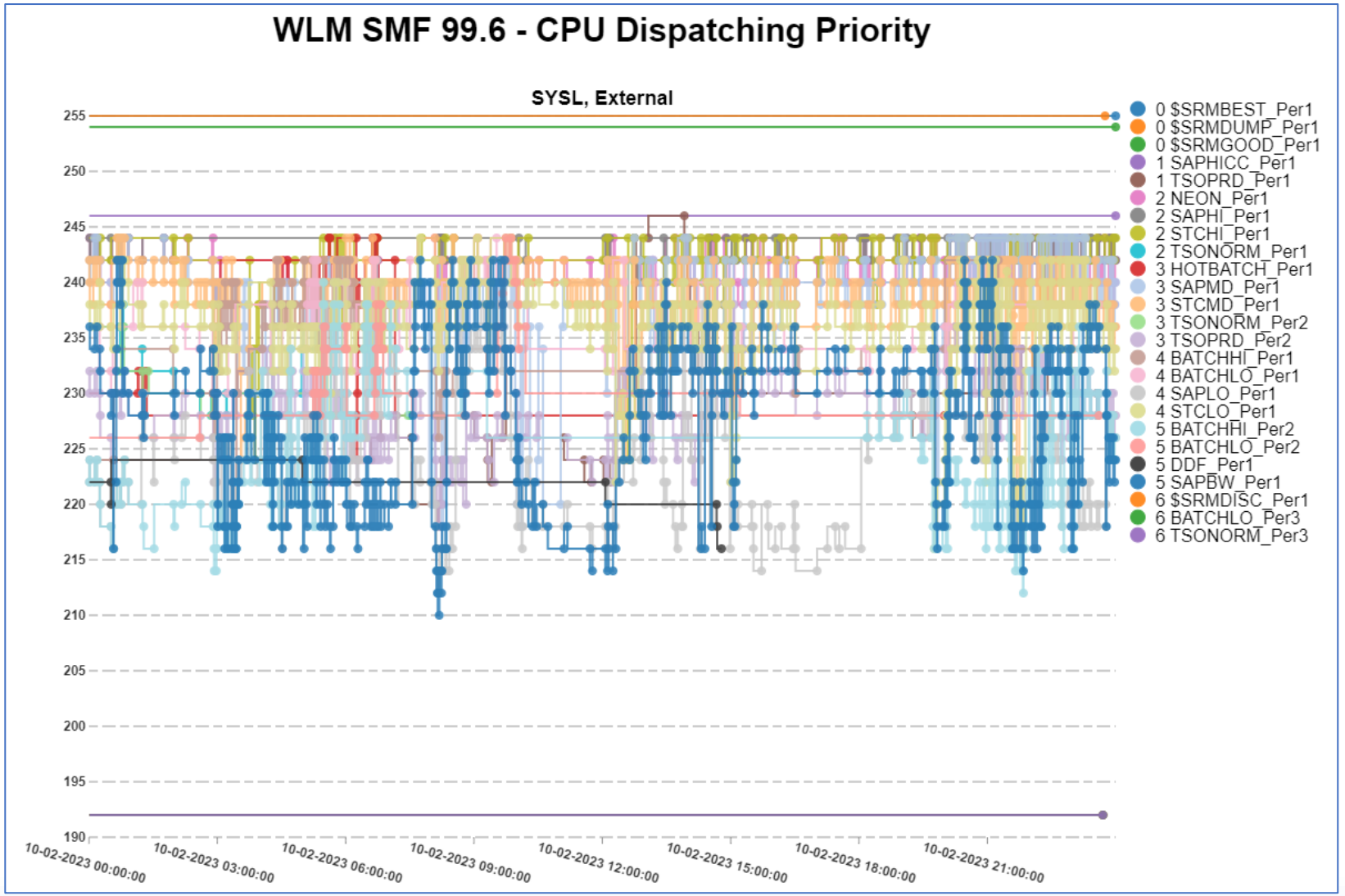
- Also, processor cache efficiencies
  - Interactive workloads tend to use processor caches less efficient
  - Batch workloads tend to use processor caches more efficiently



Assigning CPU Dispatching Priorities

- WLM sets dispatching priority for service class periods.
- All address spaces in a service class period have the same base dispatching priority
  - Note: there are ‘internal periods’ and ‘external periods’
  - There is also something called promotion (discussed later)
- Multiple service class periods may have the same base dispatching priority.
- Unbunching
  - There is a concept in the WLM algorithms called ‘unbunching’
  - After a dispatching priority change, service class periods may be remapped to different dispatching priorities such that there is an unoccupied priority between each occupied priority.

SMF 99.6 CPU Dispatching Priority – Every 10 Seconds

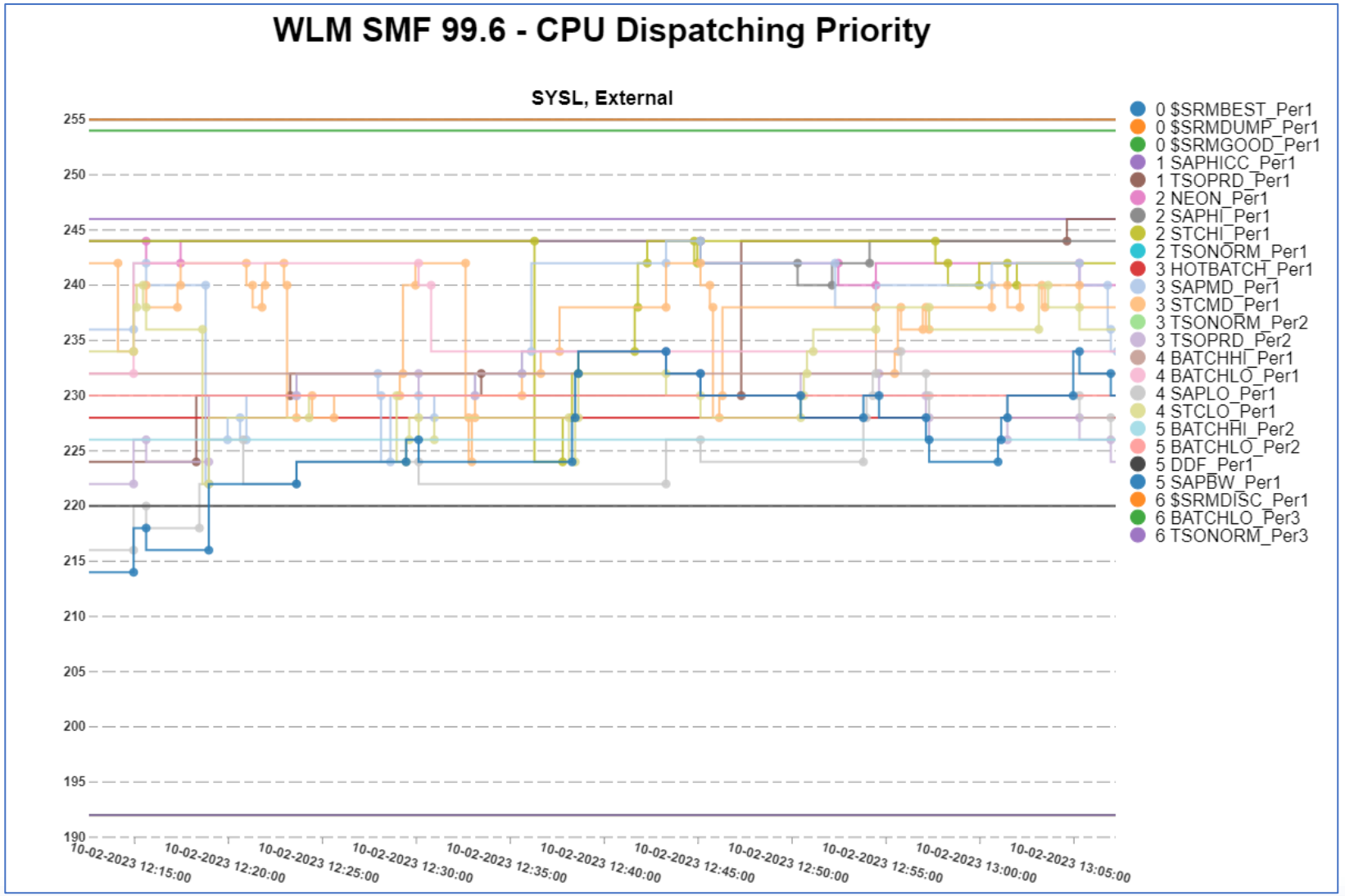


WLM service class period CPU dispatching priority for 24 hours.

Shows the CPU dispatching priority order every 10 seconds

©

SMF 99.6 CPU Dispatching Priority – Every 10 Seconds



Zoomed in from 12:14 to 13:06pm

Shows the CPU dispatching priority order every 10 seconds

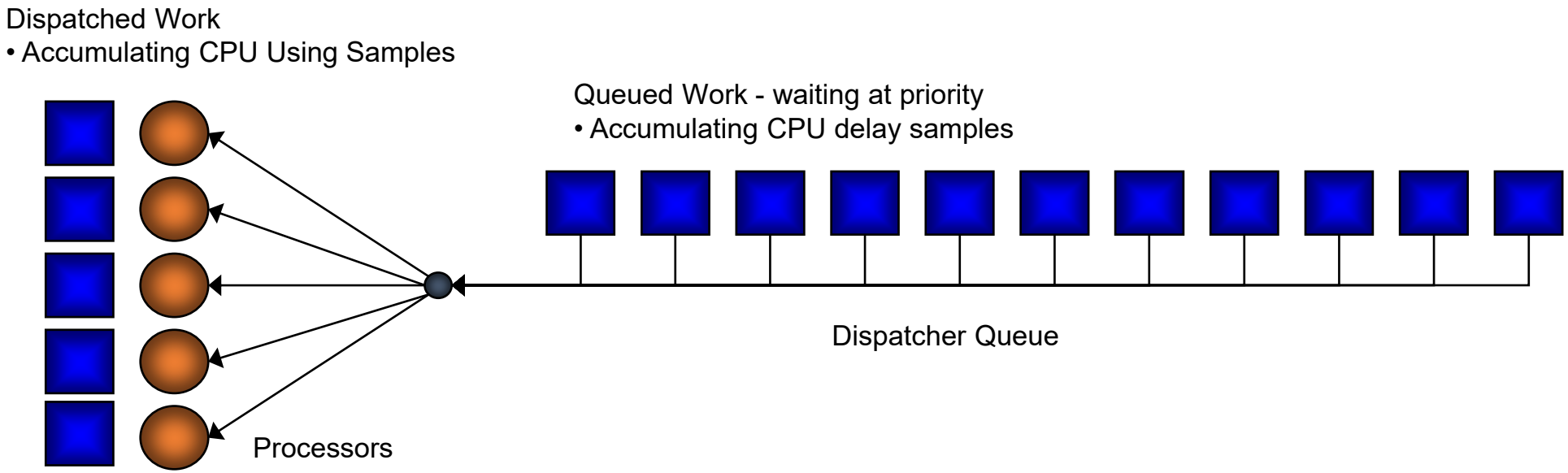
CPU Promotion:
Another reason for changing CPU DPs:

- WLM briefly ‘promotes’ individual work units to higher CPU dispatching priorities to boost the access to the CPU for very short periods of time
  - Concept:
    - If a unit of work is regularly demanding CPU and possibly holding a resource, then WLM may briefly promote the unit of work to a higher CPU DP to allow it to run for a short period of time in hopes of the work unit releasing the resource

- Reasons for promotion:
  - ENQ - Promoted by enqueue management because the work held a resource that other work needed.
  - BLK - Promoted to help blocked workloads
  - LCK - Promoted to shorten the lock hold time of a local suspend lock held by the work unit
  - SUP - Promoted by the z/OS supervisor to a higher dispatching priority than assigned by WLM
  - CRM - Promoted by chronic resource contention management because the work held a resource that other work needed

Other reasons we care about CP DP Order

- Other causes of delay include
  - Reduced preemption
    - Results in all work incurring CPU delayed from time to time
  - Fair share dispatching
    - Eliminates the need for work to be secluded to a period for micromanagement of access to the CPU



Refresher : How WLM CPU Dispatching Priority Algorithms work

Example: WLM Possible WLM Actions - CPU

- Dispatching Priority
  - Priority adjustment for
    - Periods with goals or server period
    - Discretionary periods in a resource group
  - Small consumer
    - For periods that use very little CPU
    - Gets these periods ‘out of the way’ of critical adjustments
  - Actions include:
    - Increase Receiver’s priority
    - Decrease Donor’s priority
      - Decreased service consumption and/or increased wait-to-using ratio
    - Both

255	SYSTEM
254	SYSSTC
253 249	‘Unused’ (SYSSTC1-5)
248	Small Consumer
247 203	Priorities Used for RT or Velocity Periods (i.e. Imp 1 – 5)
202	Unused
201 192	Discretionary (MTTW)
191	Quiesce

WLM Policy Adjustment – 'The Loop'

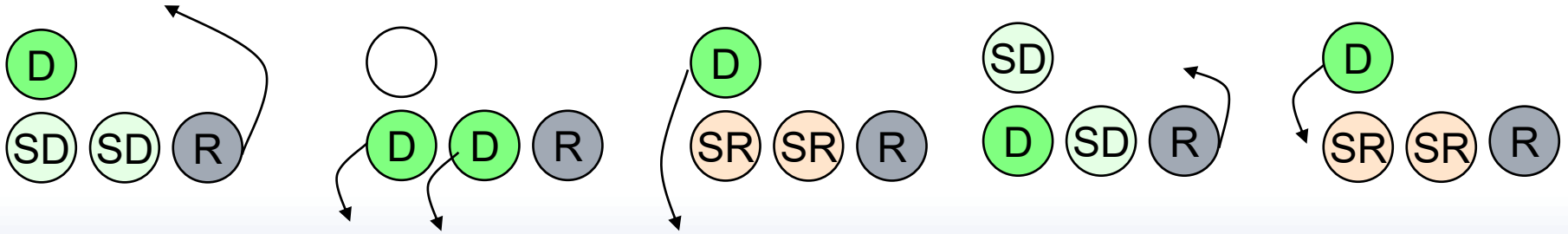
- Summarize data for state of the system and workloads
- Select a receiver period (highest importance missing goal the most)
- Find the receiver's largest bottleneck
  - Determine fix for receiver's bottleneck
    - Determine if needed resources can be gotten from unused resources
    - Find donor(s) of resource that receiver needs
    - Assess effect of reallocating resources from donor(s) to receivers
    - If allocation has both net and receiver value
      Then commit change
      Else don't make change
  - If reallocation was done
    then jump to Exit and allow change to be absorbed
  - If reallocation was not done
    then try to fix receiver's next largest bottleneck
- If cannot help receiver
  then look for next receiver (highest importance missing goal the most)
- Exit
  - Housekeep current set of controls

Receivers and Donors

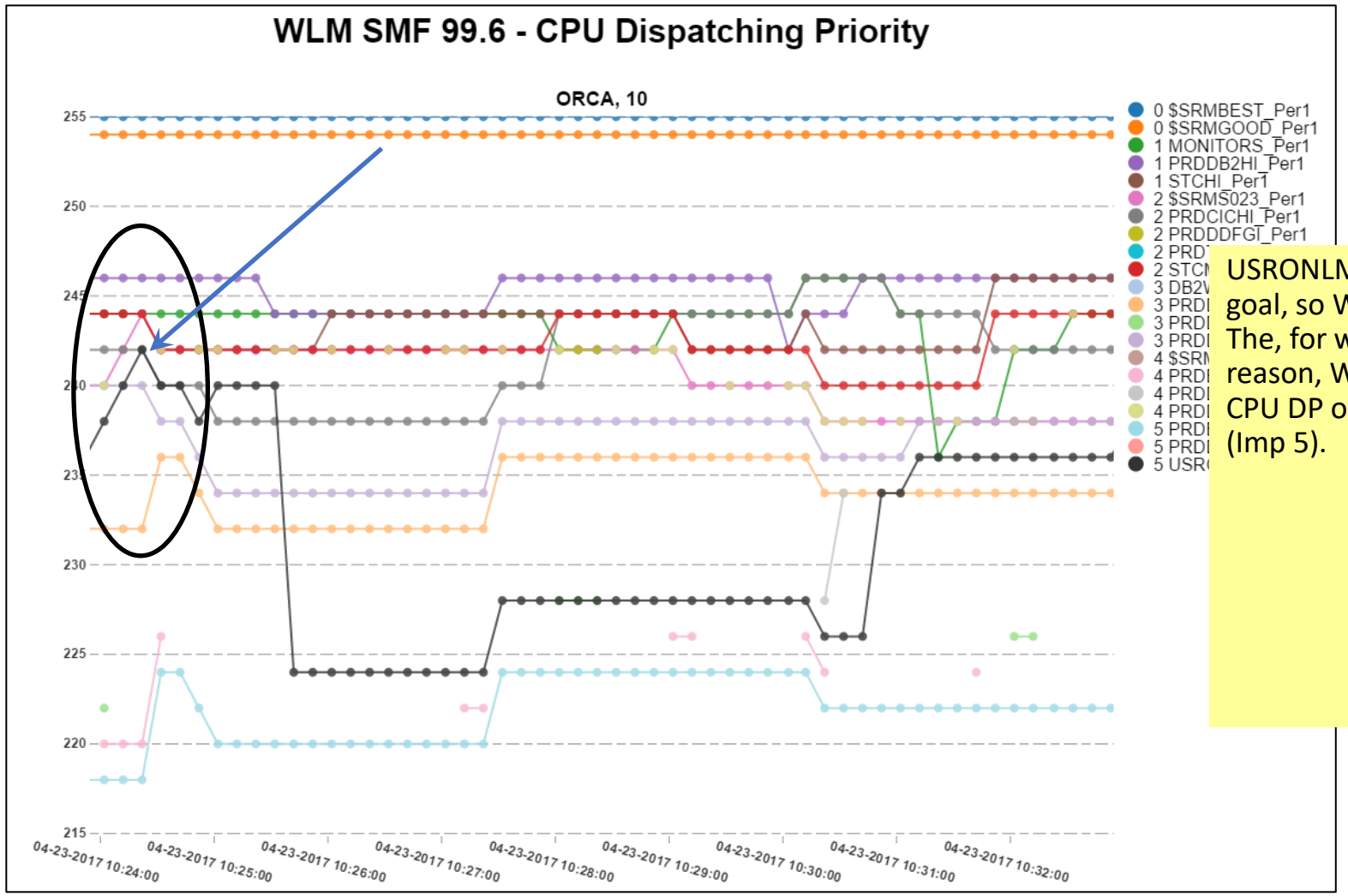
- Receiver
  - Service class period to potentially 'receive' resources
  - WLM will help only one receiver during each policy adjustment interval
    - Goal Receiver - Period with goal that needs help
    - Resource Receiver - Period to give the resources to in order to help the goal receiver
    - Secondary Receiver - Period helped indirectly due to an action to help the goal receiver
- Donor
  - Service class period to potentially 'donate' resources to help receiver
  - WLM may take from multiple donors during each policy adjustment interval
    - Goal Donor - Period whose goals may be impacted by resource donation
    - Resource Donor - Period to donate resources
    - Secondary Donor - Period that donates indirectly when receiver is helped

Example of WLM Decisions – CPU DP

- Dispatching priority adjustments
  - Objective: Increase Receiver's CPU using, or decrease Receiver's CPU delay
  - Interesting concepts:
    - Wait-to-Using ratio - ratio of CPU delay samples to CPU using samples
      (change in ratio used to determine change in CPU delay)
    - Maximum demand
      - Theoretical maximum percentage of total processor time a period may consume if it had no CPU delay
    - Achievable maximum demand
      - Percentage of total processor time a service period is projected to consume, considers demand of all higher work
  - Some possible actions



Example of a CPU DP Change



USRONLME misses goal, so WLM helps it. The, for what ever reason, WLM raises CPU DP of USRONLME (Imp 5).

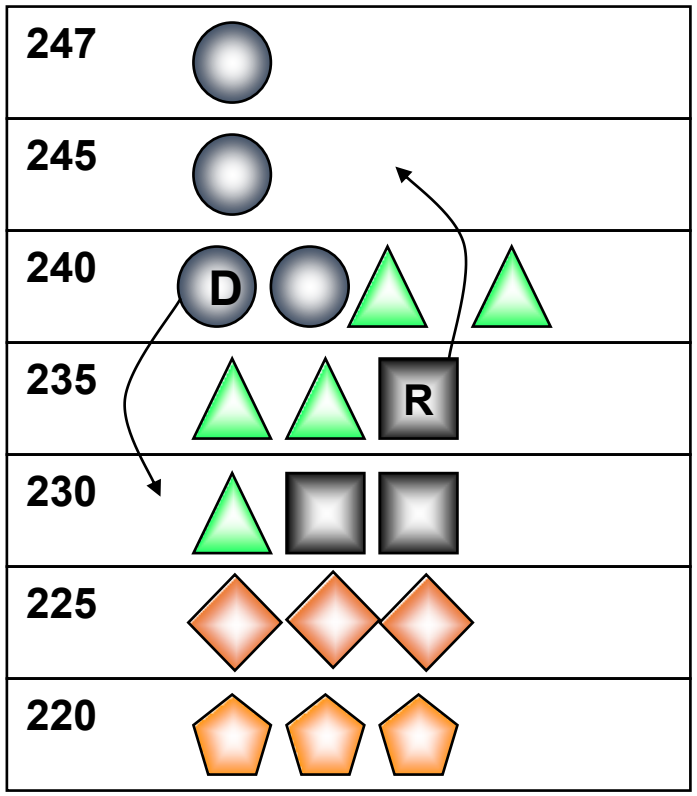
Example of WLM Actions Trace

SMFDateTime	PA Inteval	RA Interval	Trace Code	Code	Job	Local PI	Sysplex PI	Service Class	Period
4/23/17 10:24:03 AM	175	124	270	PA_REC_CAND		131	131	USRONLME	1
4/23/17 10:24:03 AM	175	124	975	PA_SDO_DONFAIL_SPC		110	110	PRDDDFGI	1
4/23/17 10:24:03 AM	175	124	975	PA_SDO_DONFAIL_SPC		70	70	PRDDDFOM	1
4/23/17 10:24:03 AM	175	124	975	PA_SDO_DONFAIL_SPC		27	27	STCME	1
4/23/17 10:24:03 AM	175	124	975	PA_SDO_DONFAIL_SPC		110	110	PRDDDFPD	1
4/23/17 10:24:03 AM	175	124	308	PA_DONOR_PERIOD		40	40	STCHI	1
4/23/17 10:24:03 AM	175	124	880	PA_PRO_RDON_CAND		40	40	STCHI	1
4/23/17 10:24:03 AM	175	124	620	PA_PMUO_REC		131	131	USRONLME	1
4/23/17 10:24:03 AM	175	124	620	PA_PMUO_REC		131	131	USRONLME	1
4/23/17 10:24:03 AM	175	124	620	PA_PMUO_REC		131	131	USRONLME	1
4/23/17 10:24:03 AM	175	124	651	PA_PMU_SPC_NXT_DP		110	110	PRDDDFPD	1
4/23/17 10:24:03 AM	175	124	940	PA_PRO_UNC_DON		40	40	STCHI	1
4/23/17 10:24:03 AM	175	124	940	PA_PRO_UNC_DON		40	40	STCHI	1
4/23/17 10:24:03 AM	175	124	940	PA_PRO_UNC_DON		40	40	STCHI	1
4/23/17 10:24:03 AM	175	124	740	PA_PRO_INCP_DON		110	110	PRDDDFPD	1
4/23/17 10:24:03 AM	175	124	740	PA_PRO_INCP_DON		110	110	PRDDDFPD	1
4/23/17 10:24:03 AM	175	124	740	PA_PRO_INCP_DON		110	110	PRDDDFPD	1
4/23/17 10:24:03 AM	175	124	780	PA_PRO_INCP_SC		110	110	PRDDDFPD	1
4/23/17 10:24:03 AM	175	124	780	PA_PRO_INCP_SC		110	110	PRDDDFPD	1
4/23/17 10:24:03 AM	175	124	780	PA_PRO_INCP_SC		110	110	PRDDDFPD	1
4/23/17 10:24:03 AM	175	124	750	PA_PRO_INCP_REC		113	113	USRONLME	1
4/23/17 10:24:03 AM	175	124	750	PA_PRO_INCP_REC		113	113	USRONLME	1
4/23/17 10:24:03 AM	175	124	750	PA_PRO_INCP_REC		113	113	USRONLME	1

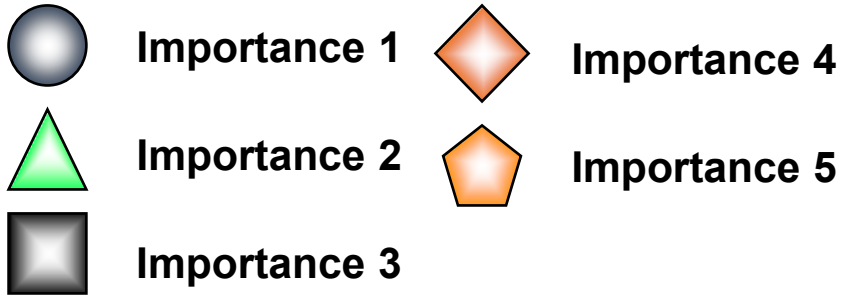
WLM CPU Critical Control

Overview of WLM CPU Critical Control

- Because some installations are concerned that WLM will not react fast enough for high priority work, WLM has a 'CPU Critical Control'



Note: To make the point, just a few priorities between DP 203 and DP247 are shown.



- With well set predictable goals, DPs tend to be ordered by importance
- If work is missing its goal WLM may decide to adjust its DP equal or above a higher importance period
- The problem occurs when this lower importance period starts to consume more CPU and causes the higher importance period to miss its goal
- WLM will recognize this condition and fix it, but WLM can be slow to react

CPU Critical aka Long-term CPU Protection

- Long-time option in your WLM service definition
- Enabled by setting YES for CPU Critical on a Service Class
  - Must be a single-period SC and cannot be discretionary
- Ensures that the CPU Critical SC always has a dispatching priority that's greater than the DP of lower importance service class periods
- Note some small amount of lower-importance work may still get higher DP:
  - Due to promotion for locks, resource contention, etc.
  - Small consumers
- General recommendation has been to avoid this option
  - Allows WLM to make better decisions about balancing overall throughput to best meet the goals of all work

> **Important:** The use of these options limits WLM's ability to manage the system. This may affect system performance and/or reduce the system's overall throughput.

Setting CPU Critical Control

- CPU Critical is set at the service class level
  - Can be set for address space, enclave, or transaction-oriented work
  - To help ensure that critical work will have a higher CPU DP than lower importance work

```
Service-Class  Xref  Notes  Options  Help
------------------------------------------------------------------------
                          Modify a Service Class              Row 1 to 2 of 2
Command ===> ____________________________________________________________

Service Class Name . . . . . : STCHI
Description  . . . . . . . . . Important non-system Started Tsk
Workload Name  . . . . . . . . STC       (name or ?)
Base Resource Group  . . . . . ________  (name or ?)
Cpu Critical . . . . . . . . . YES       (YES or NO)

Specify BASE GOAL information.  Action Codes: I=Insert new period,
E=Edit period, D=Delete period.

        ---Period---  ---------------------Goal---------------------
Action  #  Duration   Imp.  Description

  __
  __    1              1    Execution velocity of 60
****************************** Bottom of data ********************************
```

Implicit CPU Protection in z/OS 3.1

z/OS 3.1 Implicit Long Term CPU Protection

- New option for “Implicit” Long-Term CPU Protection
  - In other words, CPU Critical without having to specify it on every SC definition
- Default is “On” for importance 1 service class periods
  - Optional, but “Off”, for importance 2 and lower service class periods
- We think “On” for importance 1 workloads is a bad default
  - Could significantly change the dispatching priority of work in the system
  - Goes against historical practices of not changing defaults that change behavior
- DP/Importance inversions are common
  - I.E. Lower Importance work running with a DP above higher importance work
  - Not all such inversions are problematic
  - Not all importance 1 work really should be importance 1

From the IBM z/OS 3.1 Documentation

(z/OS 3.1 MVS Planning Workload Management SC34-2662)

"Beyond explicitly setting the CPU Critical option for single-period service classes of any importance except discretionary, CPU protection is implicitly assigned for the first period of any service class of importance 1 (and importance 2 when a boost is in effect)."

One (and only?) benefit of this: effects multi-period workloads

*"If you want to modify the importance level for automatically setting CPU protection, or even disable it, use the **CCImp** and **CCImpBoost** parameters in the **IEAOPTxx** member."*

***"Note:** Implicit CPU Critical for importance 1 work can impact the CPU distribution to lower importance work. Ensure that the goals are appropriate given their importance level. Evaluate the current distribution of CPU at different importance levels, especially those that are covered by CPU Critical to ensure that they have consistent CPU demands."*

We did an analysis of 116 systems

- Covered a variety of sizes from large to small, “IPO” to “Prod”, a couple of dozen customers
- Evaluated a day’s worth of 99.6 data from each system (over 17M records)
- Created 2 new metrics to help understand the risk/benefit:
  - For SCPs that would be bumped down:
    Inversion Risk Ratio – relative amount of CPU that would move above the SCP
  - For SCPs that would move up in priority:
    Protection Benefit Ratio – relative amount of CPU that would move below this SCP
  - Higher numbers means more potential risk/benefit
    - Can be very high if there’s a relatively large difference in the consumption of the workloads

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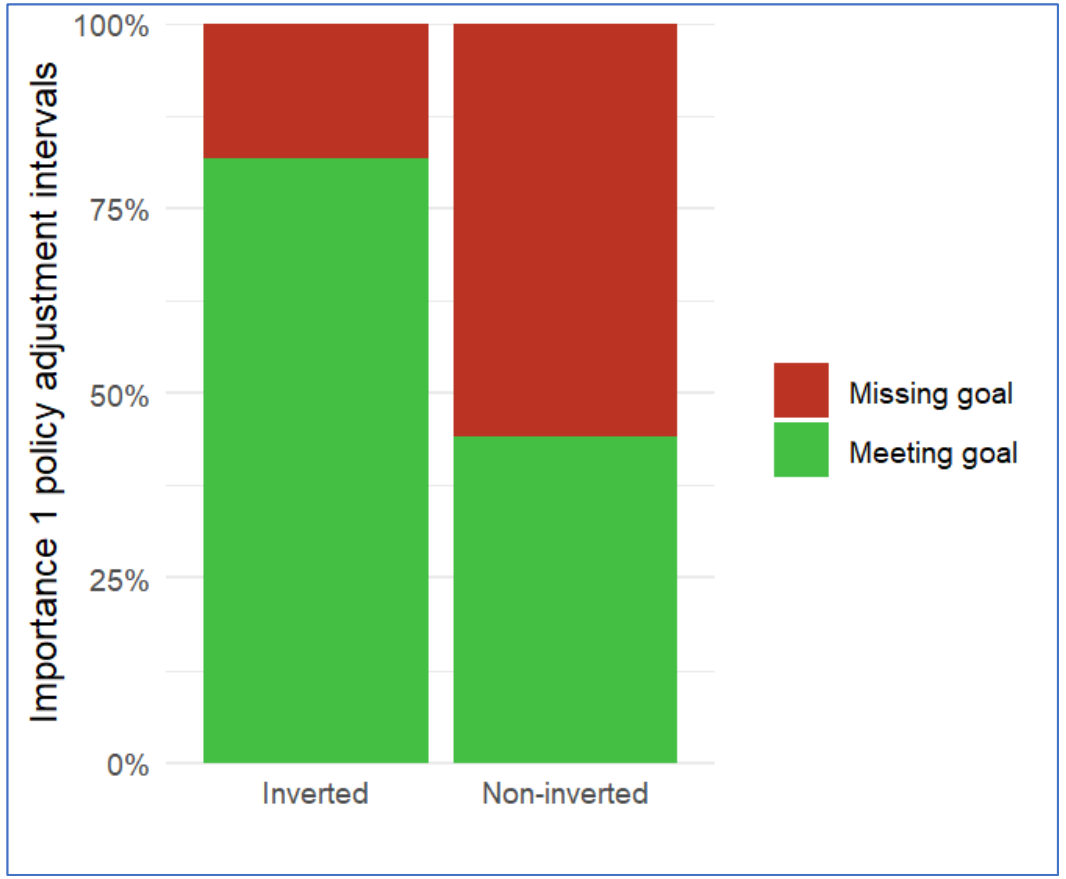
Effectiveness of z/OS pre-3.1 WLM

- z/OS pre-3.1 WLM behavior sufficiently protects importance 1 workloads and properly balances workload performance across all importance levels

- Study shows Importance 1 workloads which are running at a lower priority than lower-importance workloads are already meeting their goals more often than those running above all lower importance work (82% to 44%)

- It is important to note the limitations of this metric, as goals are not always assigned in accordance with actual needs and expectations



Notes: Inversion Risk Ratio

- The ratio of CPU service of importance 1 work to lower-importance work that is running at a higher dispatching priority (excluding work at DP 248)
  - Basically: more importance 1 work is about to move above a particular SCP, means that SCP is at greater risk
  - E.G. you have SCP A (importance 2) consuming 50 SUs that's running above importance 1 work consuming 5000 SUs. SCP A has an inversion risk ratio of 100.
  - Higher numbers = more risk, but even ratios < 1 represent some risk
  - Risk = Might not get as ready access to CPU, might suffer more CPU delay

Notes: Protection Benefit Ratio

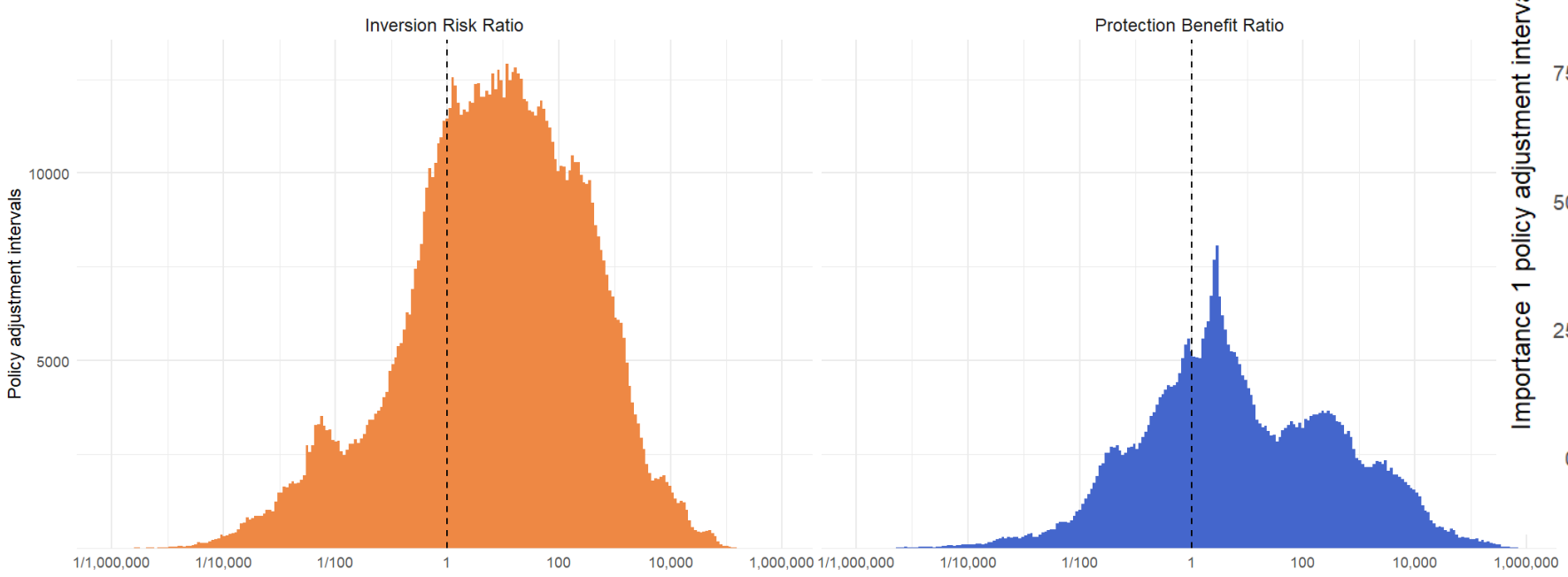
- The ratio of CPU service of lower-importance work that is running at a higher dispatching priority (excluding work at DP 248) to importance 1 workload
  - Basically: more lower importance work is about to move below an importance 1 SCP, means that importance 1 SCP might get a bigger benefit
  - E.G. you have SCP Z at importance 1 and consuming 80 SUs but it's running below lower importance work that's consuming 4000 SUs. SCP Z has a Protection Benefit Ratio of 50.
  - Higher numbers = more potential benefit, but even ratios < 1 represent some possible benefit.
  - Benefit = might get easter/faster access to CPU, might see less CPU delay

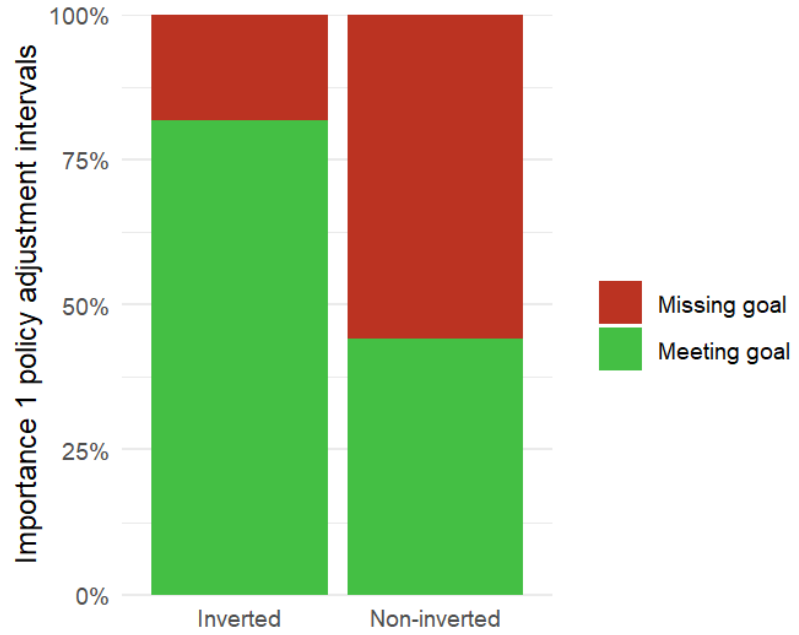
Histograms

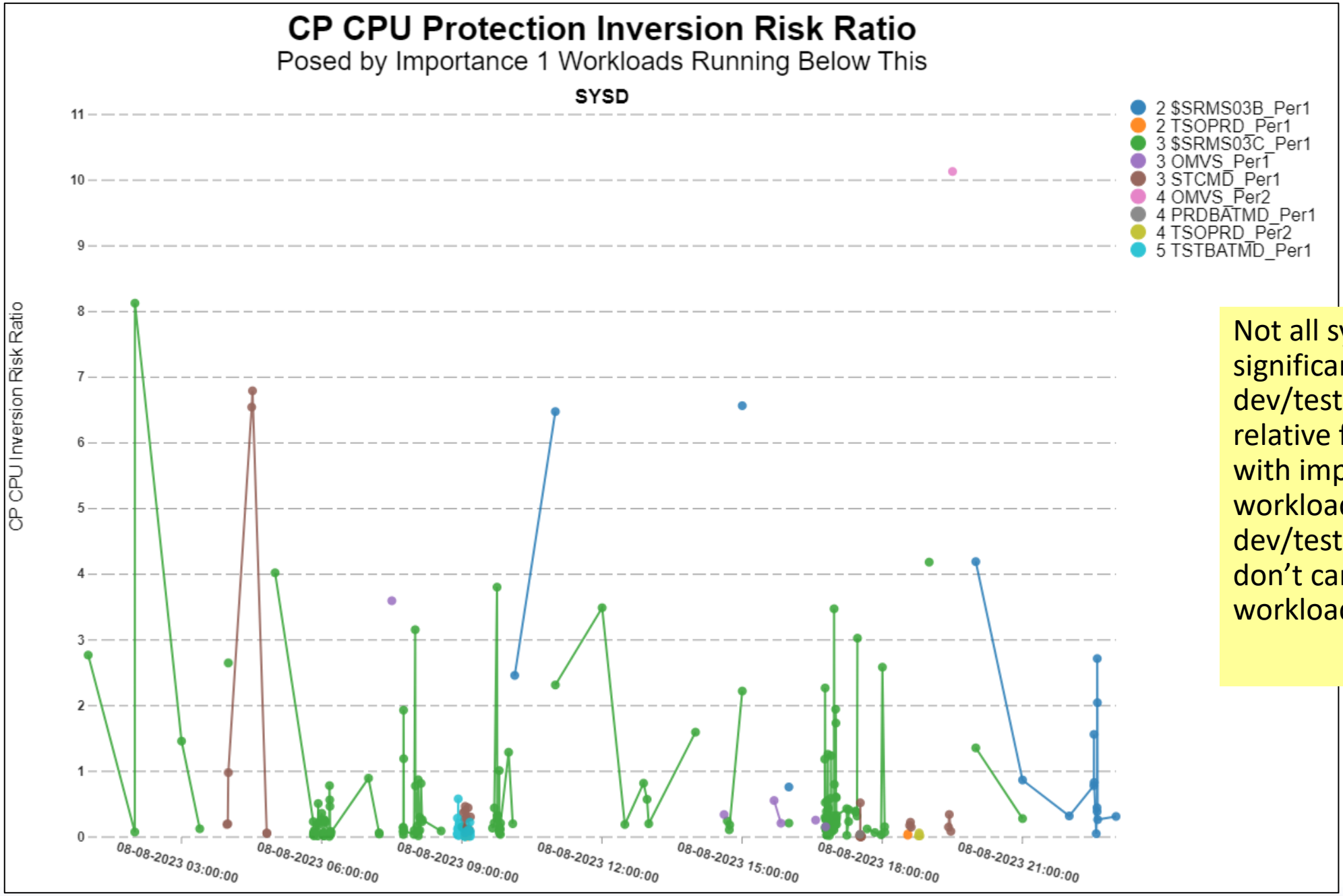
- The next slide has two histograms:
  - On the left, the Inversion Risk Ratio across all such service class periods which are running above an importance 1 workload in the 116 systems. (Total ~1 million service class policy adjustment intervals)
  - On the right, the Protection Benefit Ratio, across all importance 1 SCPs running below lower-importance workloads in the 116 systems. (Total, ~434,000 service class policy adjustment intervals)
- There are instances of very high ratios in both cases, but overall, there's more SCPs at risk than they are that stand to benefit.
  - And most of SCPs that might benefit are already meeting their goals
  - For those that have set goals appropriate to the workload's actual performance needs, the risks may very well outweigh any potential benefits

Study findings

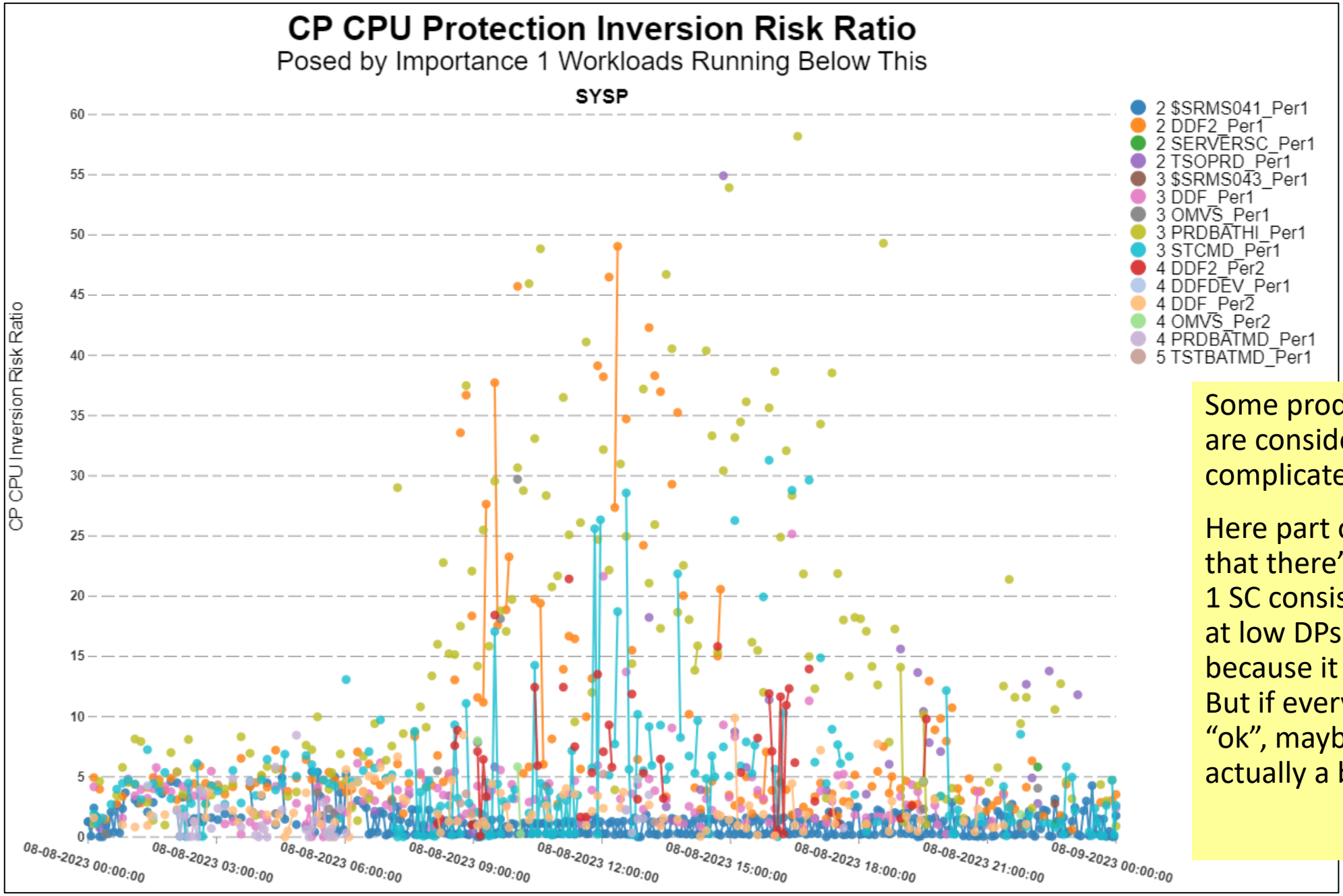
- 78% of systems had at least one interval with an inversion
- 39% of systems had inversions in at least 25% of their intervals
- 82% of “Inverted” Importance 1 workloads were meeting their goal







Not all systems will have significant risk. This dev/test system has relative few inversion with importance 1 workloads. And it's dev/test: maybe you don't care if those workloads suffer more.



Some production systems are considerably more complicated!

Here part of the issue is that there's an importance 1 SC consistently running at low DPs. That might be because it has a poor goal. But if everything is running "ok", maybe it's not actually a bad goal.

The dumbing down of WLM

- In the age of AI, it is strange that IBM is choosing to dumb down WLM
  - Customers could already choose to do this… so why the new forced default?
  - Also, the disablement is in the IEAOPTxx rather than the WLM service definition
- Defaulting all importance 1 workloads to CPU Critical may have significant impacts
  - "Fixing" these inversions is likely to have a larger negative impact on the lower importance workload than it will a positive impact on the importance 1 workloads
- Making this the new default disregards:
  - The practice of avoiding changing defaults that would change the behavior of the system
  - Long-standing recommendations to generally avoid the use of CPU Critical
- It is not correct to assume that all work is classified to the proper importance and given a proper goal that is consistent with the business and technical requirements, but it's also not correct to assume goals were improperly set as well.

Our thoughts (at this time)

- We don't see the need for this change
  - A significant part of the premise of WLM was that it would manage dispatching priorities and could intelligently move them in possibly counter-intuitive ways to better balance throughput for diverse workloads
  - If you want, you can make all importance 1 work CPU Critical today (at least for single-period SCs)
- We'd recommend turning this off for z/OS 3.1 and wish that was the default
- If you want to go to z/OS 3.1 with it on, we might suggest
  1. Evaluate which workloads are at risk
  2. Before z/OS 3.1, incrementally add CPU Critical to importance 1 workloads
     - If something goes wrong, you can back out your change and z/OS 3.1 doesn't get the blame
- We do sometimes recommend CPU Critical, but it's an exception, not the rule
- Again: emerging area of study, we might refine our recommendations over time

If you want more details…

- White paper available:
  Summary of Potential Impact of Implicit Long-Term CPU Protection
  - For a copy, please send an email to performance.questions@epstrategies.com

- **Special thanks to Ethan Chapman for his statistical and R expertise!**

- QUESTIONS?