Multi Core Playground

How can we get the most out of our modern CPU's?

Arden Thomas
Cincom's Smalltalk Product Manager

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Multi-Core Computers

- Are becoming ubiquitous….
- Quad cores from Intel & AMD are becoming commonplace
- 8,16,64 cores around the corner?

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Cincom Smalltalk™ Roadmap Item

- *“Research ways to leverage Multi-Core computing”*
- This item was a magnet – lots of interest

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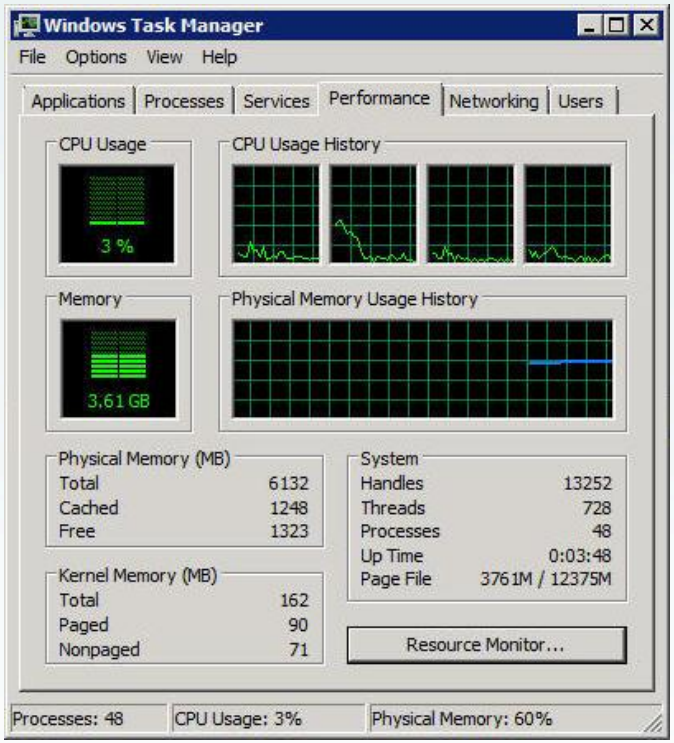
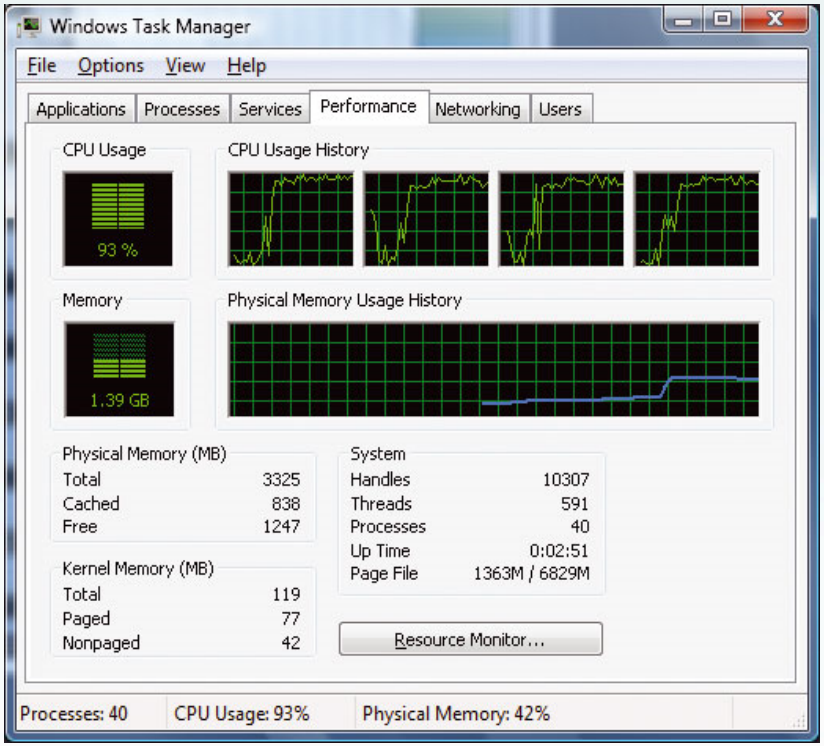
What is the Attraction?

- Making the most of what you have:





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Rear Admiral Grace Murray-Hopper

- Distinguished computer scientist
- Was there when they took a moth out of the relays of an early computer (*"getting the bugs out"*)
- Had a great ability to convey ideas in easy to grasp perspectives

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Grace Murray-Hopper

“When the farmer, using a horse, could not pull out a stump, he didn’t go back to the barn for a bigger horse,

he went back for another horse.”

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Using Multi-Core Computers

- “Team” of horses
- Type of concurrent programming
- On the same machine / OS
  - Generally faster
  - More options (i.e. shared memory, etc)

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…A ‘Small’ Matter of Programming….

- Most Concurrency is NOT EASY
- Concurrency problems and solutions have been studied for decades

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…A ‘Small’ Matter of Programming….

- Both AMD & Intel have donated money and personnel to Universities doing concurrency research
  - Specifically with the intent of increasing market demand for their products

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…A ‘Small’ Matter of Programming….

“As the Power of using
concurrency
increases linearly,
the complexity
increases exponentially”

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Approaches to Using Multi-Cores

Multiple Applications

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Approaches to Using Multi-Cores

- Multiple Applications
- Advantages
  - Simple
  - Easy
  - Effective
  - Minimal contention
- Disadvantages
  - Multiple independent applications needed
  - Not necessarily using multi-cores for one problem

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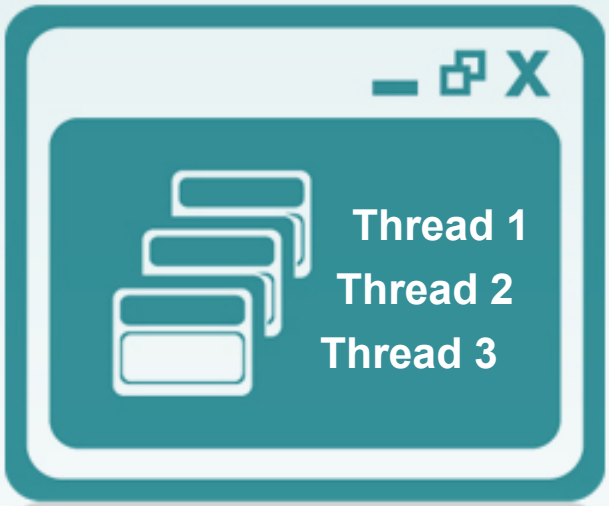
Approaches to Using Multi-Cores



Multiple Process Threads in a Single Application

Core 1 | Core 2 | Core 3 | Core 4

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Approaches to Using Multi-Cores

- Multiple Process threads in a single application
- Advantages
  - Threads have access to the same object space
  - Can be effective concurrency
- Disadvantages
  - Object contention and overhead
  - Usually significant added complexity
  - Threads (if native) can take down the whole application in severe error situations

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Approaches to Using Multi-Cores

- Multiple Process threads in a single application
  - Multiple “green” (non native) threads available in VisualWorks/ObjectStudio8
- This can still be very effective
  - Modeling producer/consumer problems
  - Effective example later

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Some Smalltalk Objects for Concurrency

- Process
- Semaphore
- Promise (a kind of ‘Future’)
- SharedQueue

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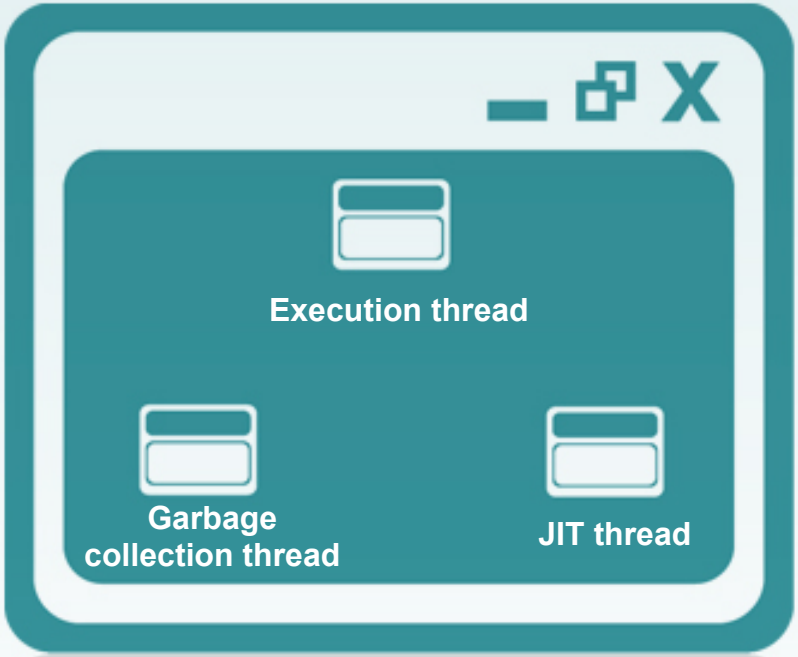
Approaches to Using Multi-Cores

Multiple Process Threads in a CST VM



Core 1 Core 2 Core 3 Core 4

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Approaches to Using Multi-Cores

- Multiple Process threads in a CST VM

  Note that the idea is just an example for discussion, product management brainstorming

- Advantages
  - Use of multi-cores even with single threaded applications
- Disadvantages
  - Time & resources to develop VM
  - Feasibility and stability questions

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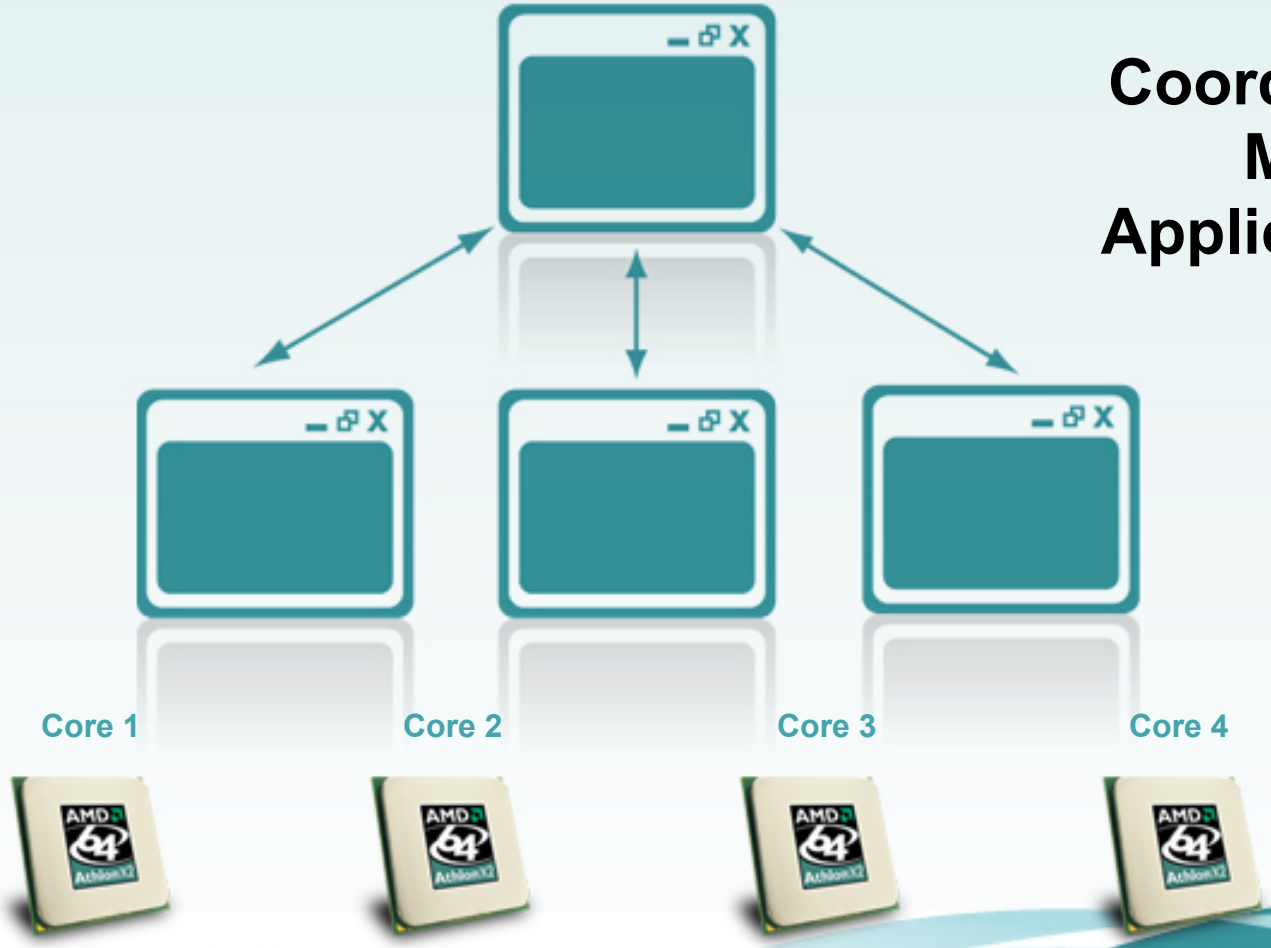
Approaches to Using Multi-Cores

Coordinated Multiple Applications



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Approaches to Using Multi-Cores

- Coordinated Multiple Applications
- Advantages
  - Smaller changes in code needed
  - Fairly Easy & Effective
  - Could be Scaled to number of Cores
  - Fewer contention issues
  - Doable without VM changes
- Disadvantages

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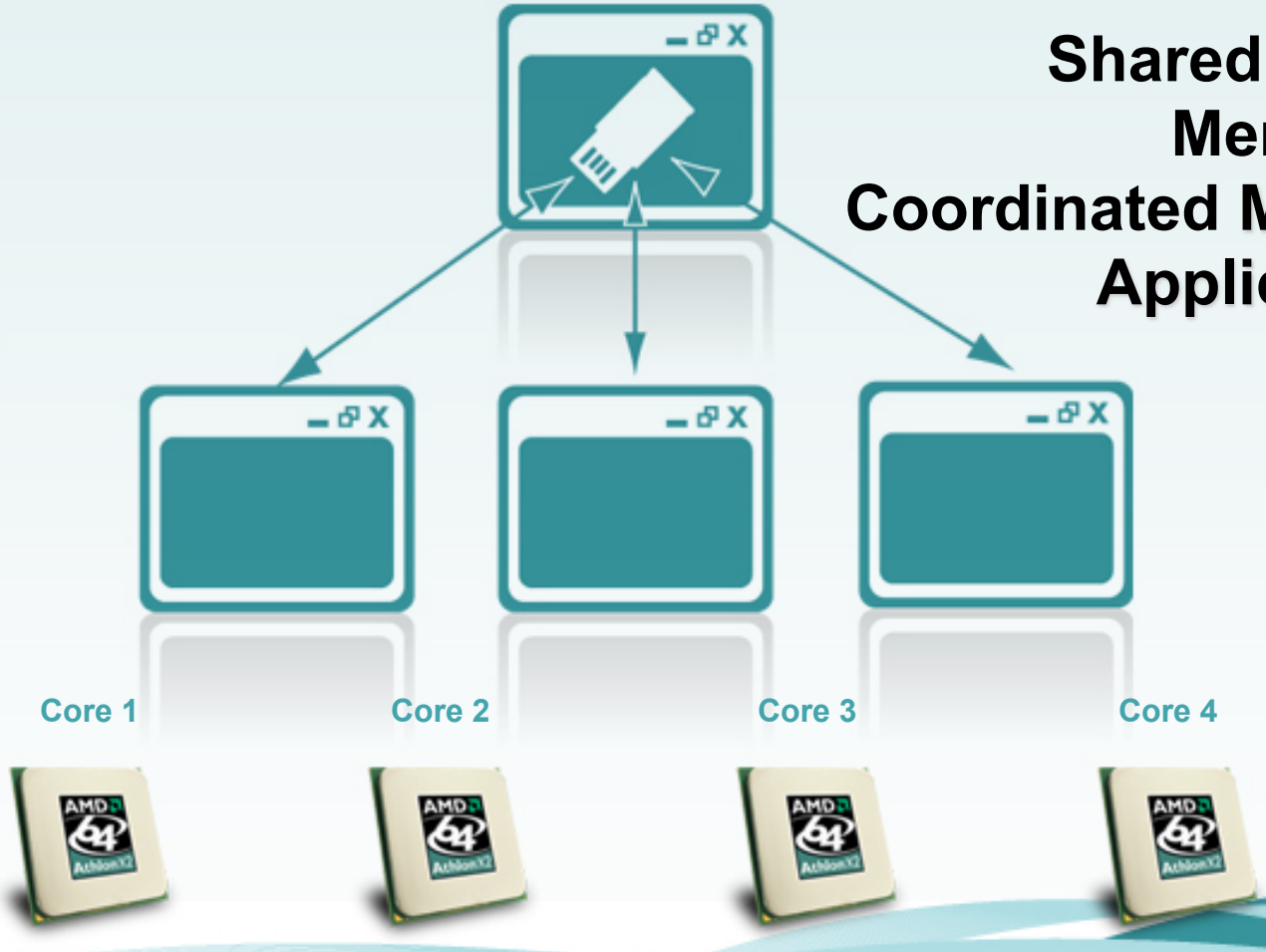
Approaches to Using Multi-Cores



Shared Object Memory & Coordinated Multiple Applications

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Approaches to Using Multi-Cores

- Shared Object Memory with Coordinated Multiple Applications
- Advantages
  - Can solve a broader set of problems
  - Can bring multiple cores to bear on the same object set
- Disadvantages
  - Garbage collection complications
  - Need to coordinate or manage sharing (traditional concurrency problems)

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Product Management Requirements

- Research into ways to utilize multi-core computers
  - We can add multiple facilities & abilities over time
- Something "Smalltalk simple“
  - A simple mechanism that is simple, effective, and high level
  - Not Smalltalk implementation of generally hard things
- Avoids most of the traditional problems and difficulties if possible
  - Minimize contention, locking, ability to deadlock
- Is flexible enough to be the basis for more sophisticated solutions as situations warrant

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Polycephaly

- Engineering experiment
- Assists in starting and managing headless images
  - Handing them work
  - Transporting the results

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Polycephaly – What it Isn't

We have not magically invented some panacea to the difficult issue of concurrency

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Polycephaly – What it Is

- A simple framework that allows a subset of concurrency problems to be solved
- For this class of problems, it works rather nicely

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Experiment

- Take some code that performs a task
- See how overall time to perform the task could be improved, using concurrency
- Use the Polycephaly framework
- Goal:
  - See if substantial improvements, via concurrency could be made with a small, minor and simple amount of effort.

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Task

- Loading market security information
  - Stocks
  - Mutual Funds
  - ETFs
- Two Sources
  - Files from Nasdaq
    - For NYSE, AMEX, Nasdaq
  - HTTP
    - Mutual Funds (around 24,000!)

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Baseline Code

- Original sequential load code:

```
nyse := Security loadNYSE.
amex := Security loadAMEX.
nasd := Security loadNasdaq.
funds := MutualFund load.
etfs := ETF load.
```

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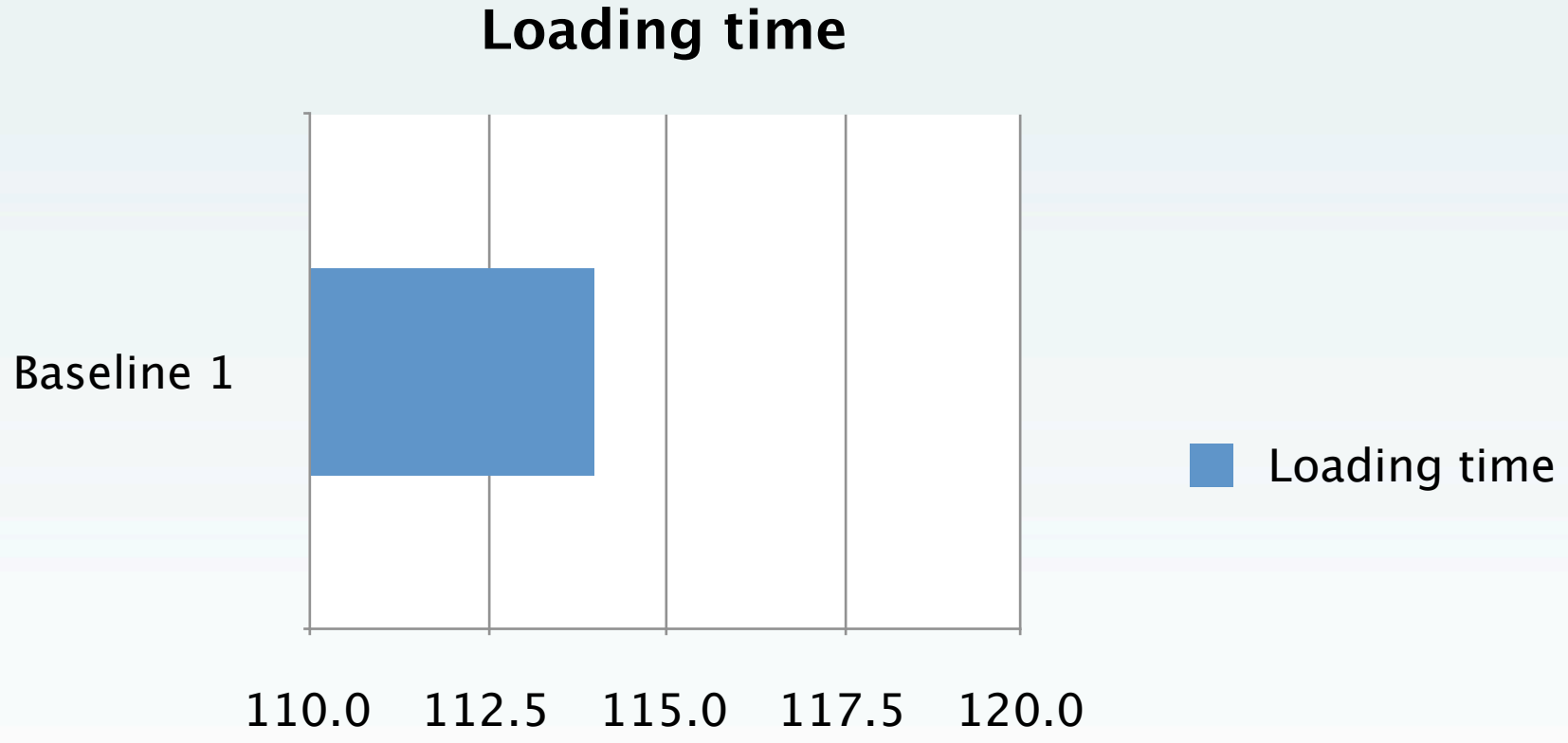
Time Baseline - Code Run Sequentially



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Experiment I

- Make the five loads work concurrently using Polycephaly

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Experiment I

- Concurrent load code:
  nyseLoad := self promise: ‘Security loadNYSE'.
  amexLoad := self promise: ‘Security loadAMEX'.
  nasdLoad := self promise: ‘Security loadNasdaq'.
  fundsLoad := self promise: ‘MutualFund load'.
  etfsLoad := self promise: ‘ETF load'.

- nyse := nyseLoad value.
  amex := amexLoad value.
  nasd := nasdLoad value.

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Experiment I

- promise: aString
  | machine |
  machine := VirtualMachine new.
  ^[| val |
  val := machine doit: aString.
  machine release.
  val] promise

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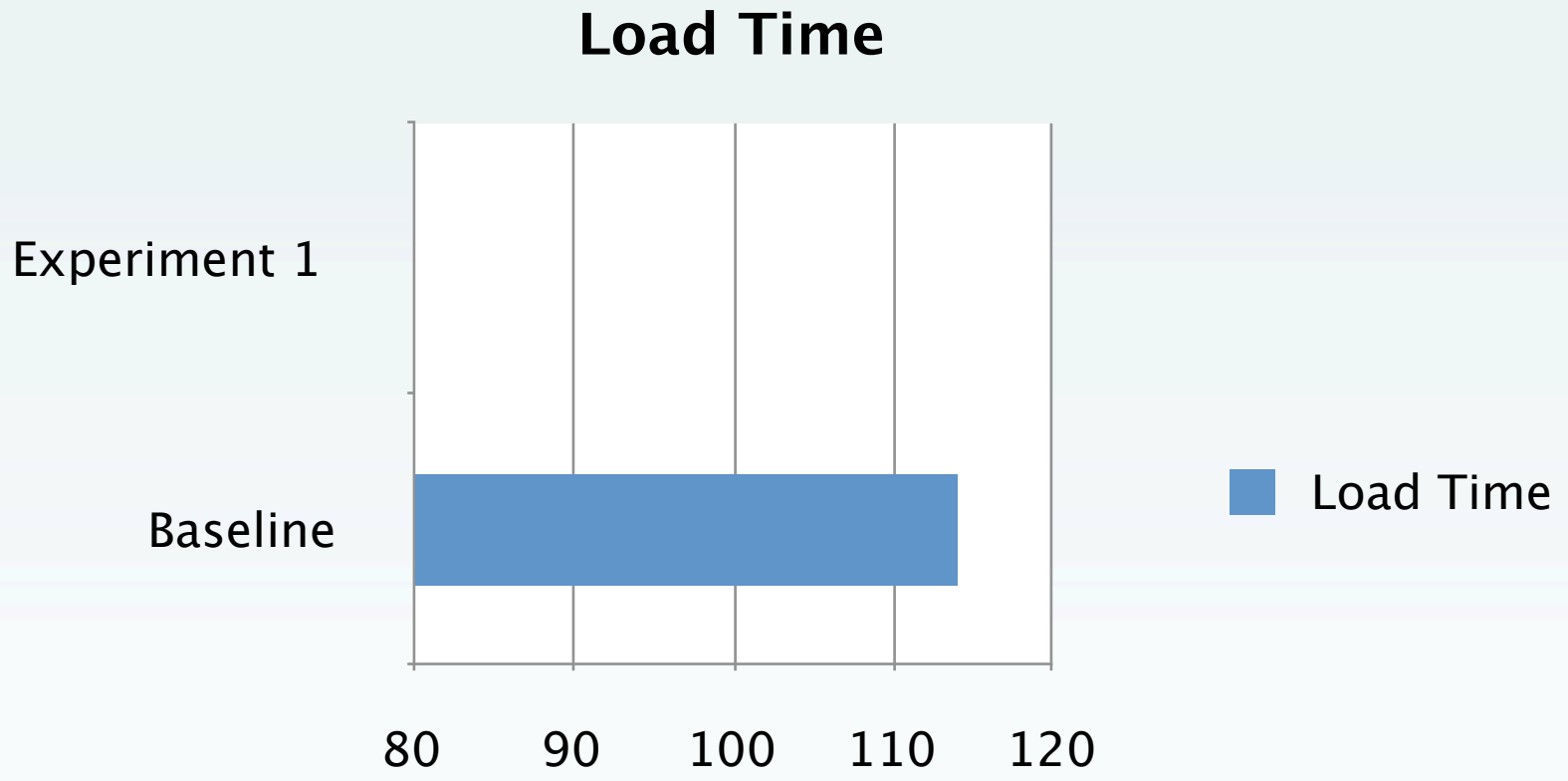
Experiment I



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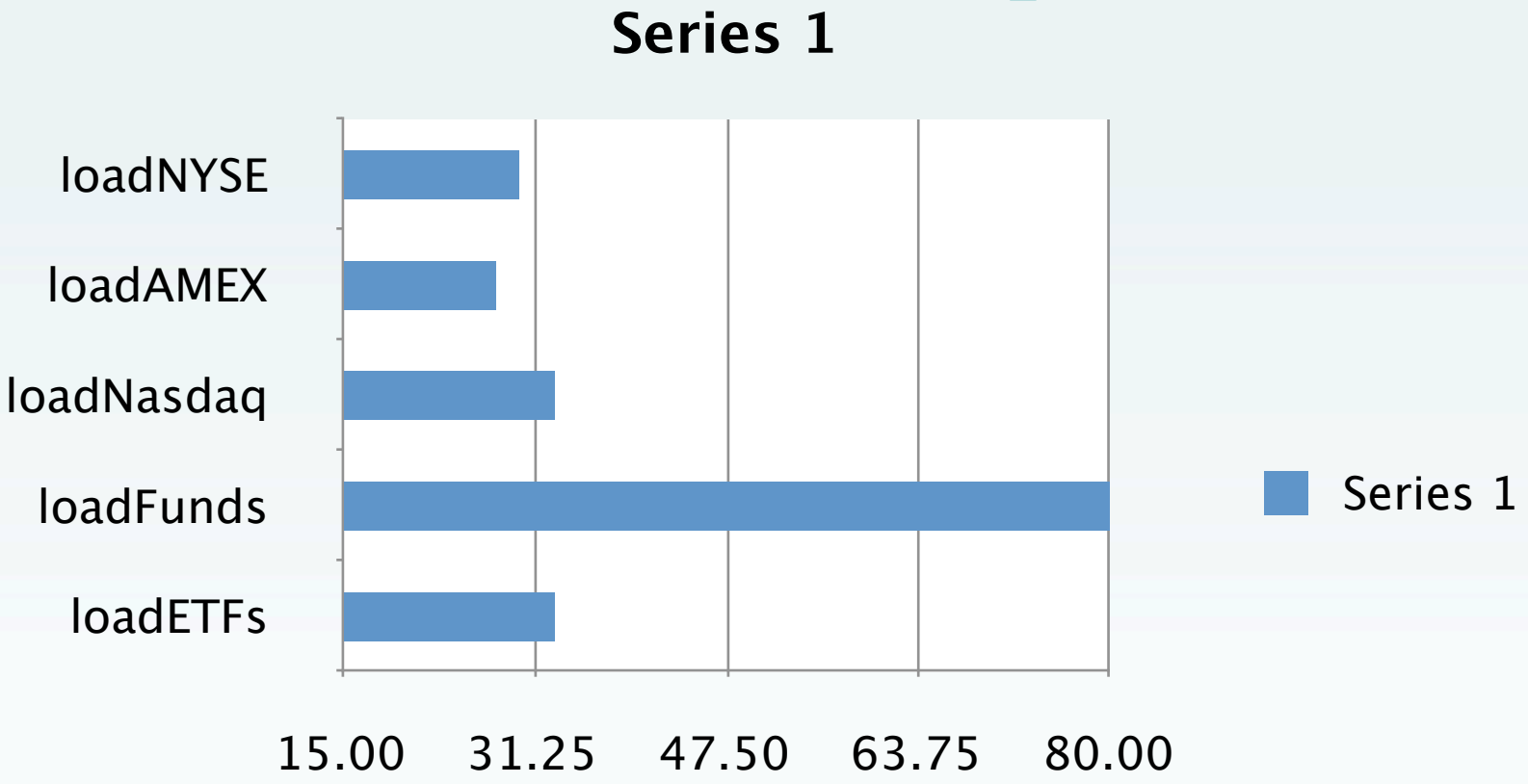
Experiment I



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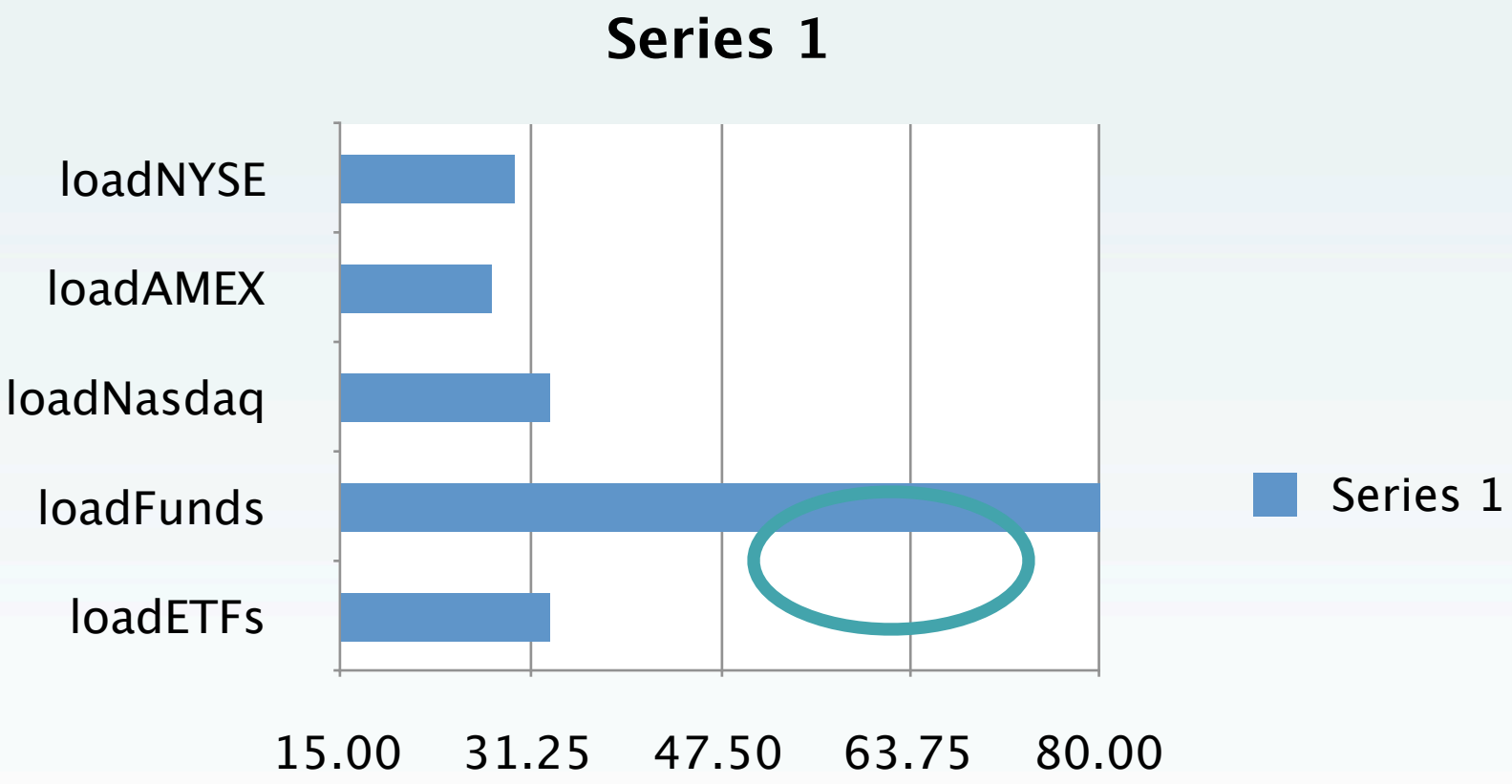
Experiment I - Bottleneck



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Experiment II – Addressing the Bottleneck

- loadFunds took the majority of the time
- Loads information for over 24,000 Mutual Funds
- Loads via http
- Loads all Funds starting with ‘A’, then ‘B’ ….
- So try making each letter an independent task ….

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Experiment II – Addressing the Bottleneck

- Create n “drones” (start n images)
- Each drones grabs a letter and processes it
  - Then returns the results to the requesting image
- When done it asks for another letter
- For n from 3 to 20

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Experiment II – Addressing the Bottleneck

- Time with: 3 drones: 30244
  Time with: 4 drones: 22373
  Time with: 5 drones: 20674
  Time with: 6 drones: 18271
  Time with: 7 drones: 18570
  Time with: 8 drones: 17619
  Time with: 9 drones: 17802
  Time with: 10 drones: 17691
  Time with: 11 drones: 19558
- Time with: 12 drones: 18905
  Time with: 13 drones: 17658
  Time with: 14 drones: 19696
  Time with: 15 drones: 21028
  Time with: 16 drones: 19704
  Time with: 17 drones: 21899
  Time with: 18 drones: 19400
  Time with: 19 drones: 19884
  Time with: 20 drones: 20698

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Experiment II – Addressing the Bottleneck

- Points to note about the solution
  - Times include
    - Start-up of drone VM's
    - Object transport time

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Experiment III – Addressing the Bottleneck, Revisited

- Lets take another look at the problem
- 26 http calls
  - Call
  - Wait
  - Process
  - Repeat

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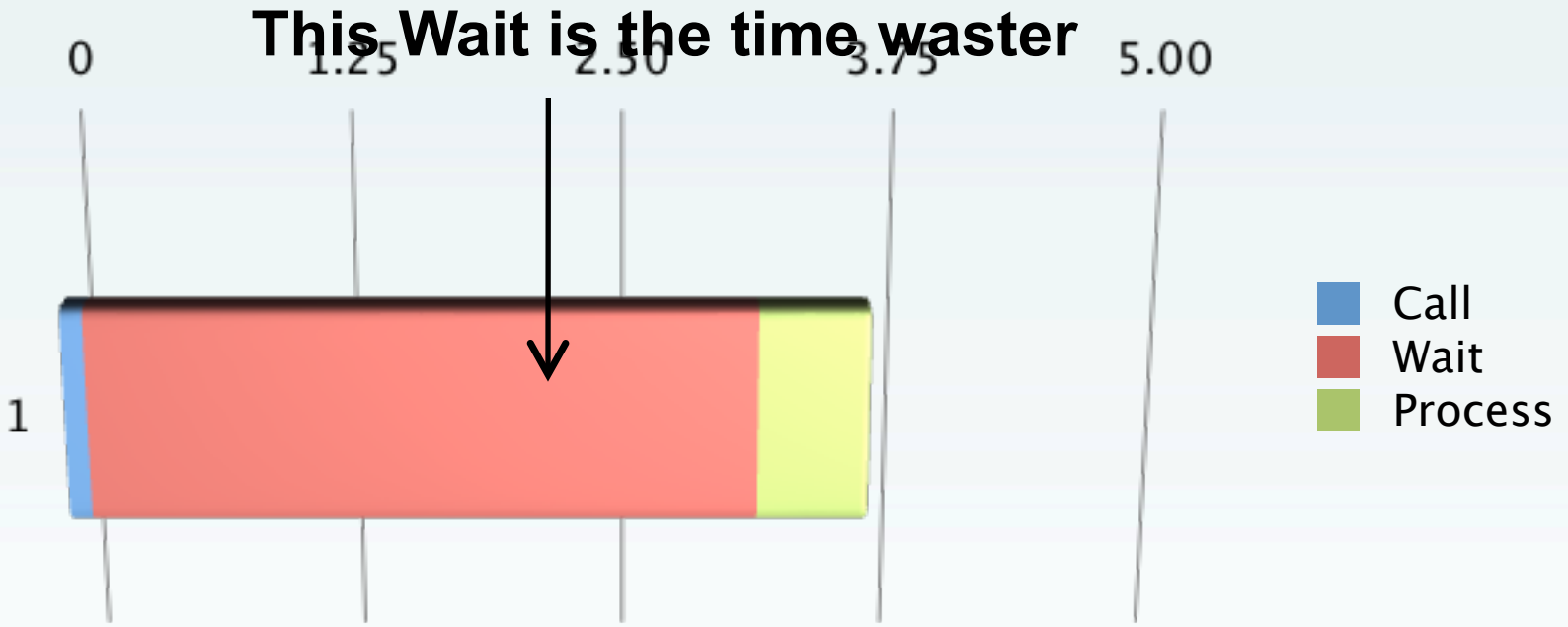
Bottleneck Revisited– the Orange Issue



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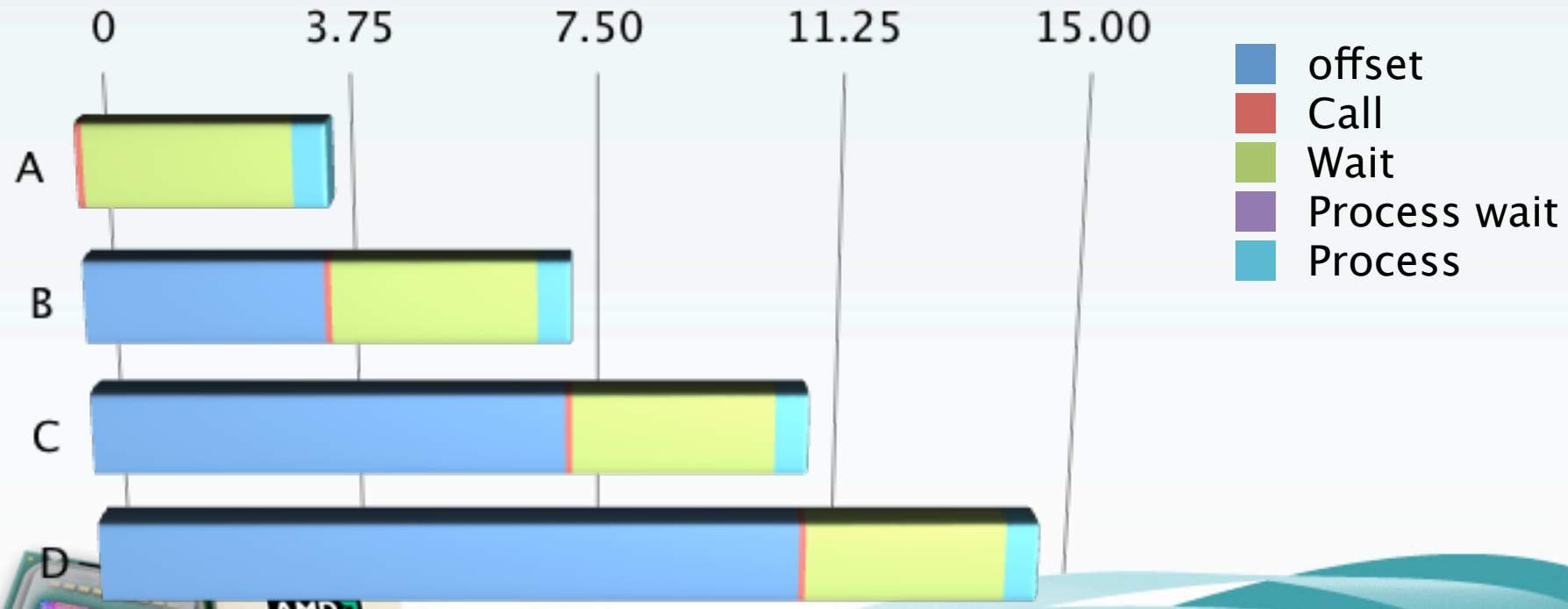
Bottleneck Revisited- Sequence



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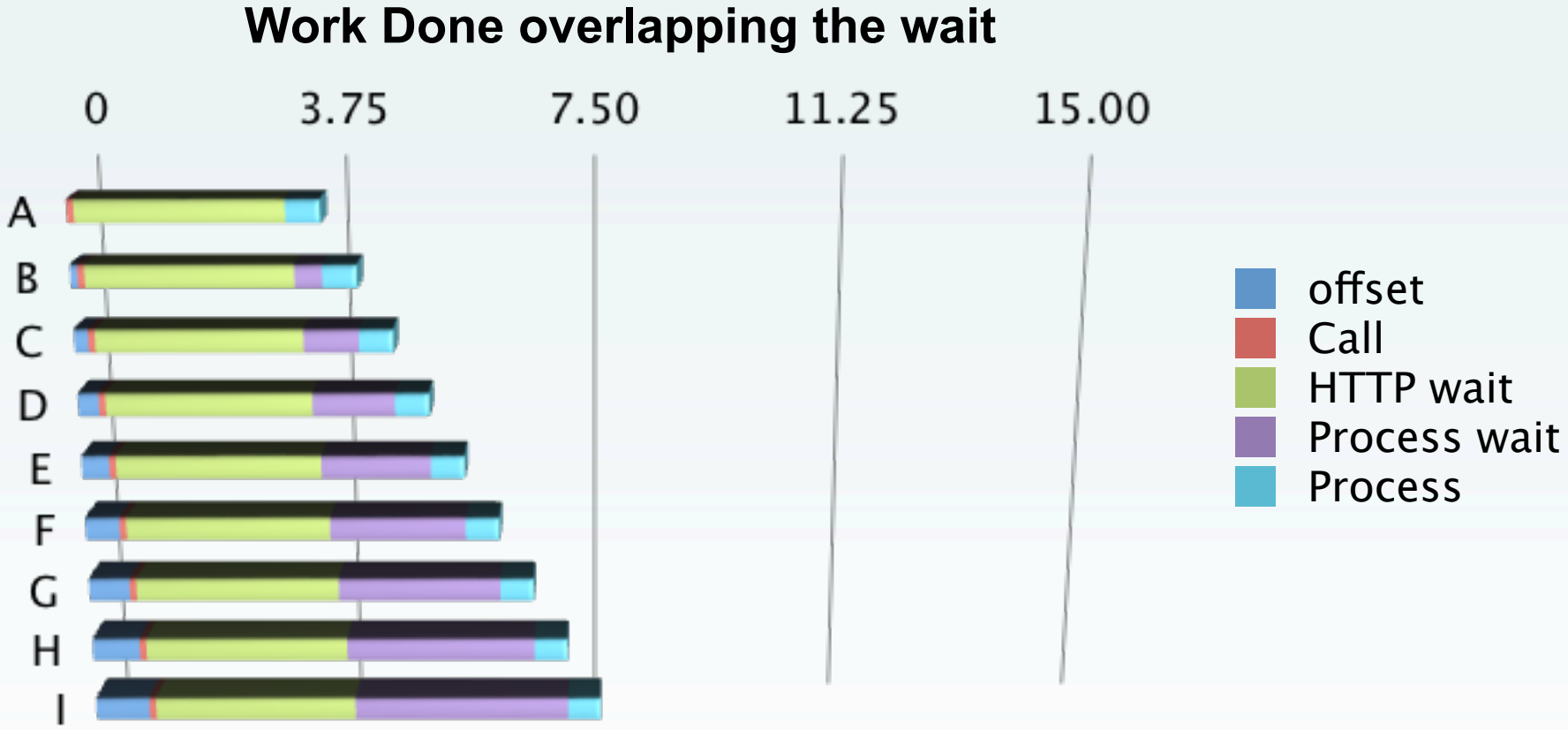
Bottleneck Revisited – Overlap Solution



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Code for the Curious ....

```
1 to: n do: [:i |
[ | char |
    [char := queue nextAvailable. char isNil]
       whileFalse: [results nextPut: (Alpha.MutualFund  loadForChar: char )].
    done signal] fork].
n timesRepeat: [done wait].
```

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Bottleneck Redux – Overlap Solution

- Results
  - Used 13 green threads
  - Reduced the load time to *15 seconds*!
  - All in one image

What about 26 threads?

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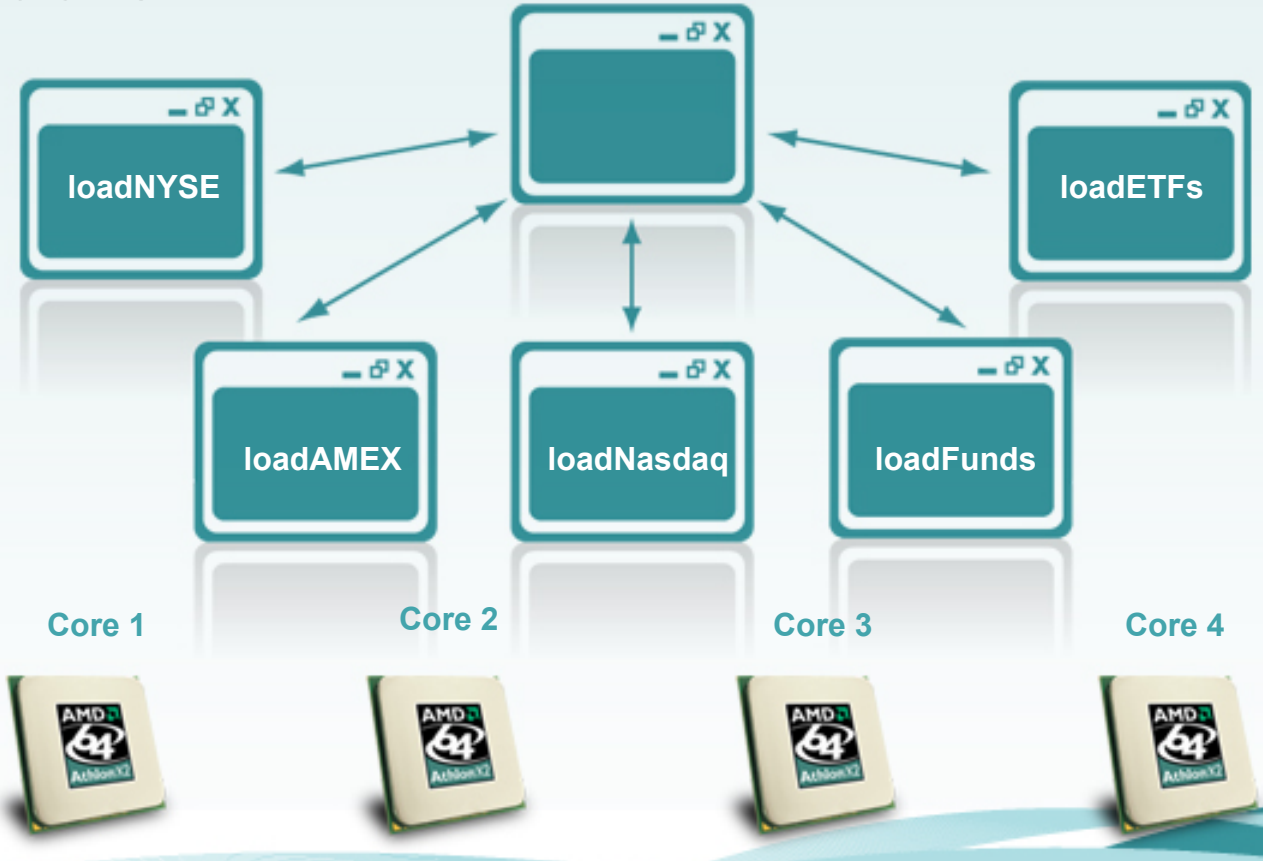
Putting it All Together

Coordinated Multiple Applications



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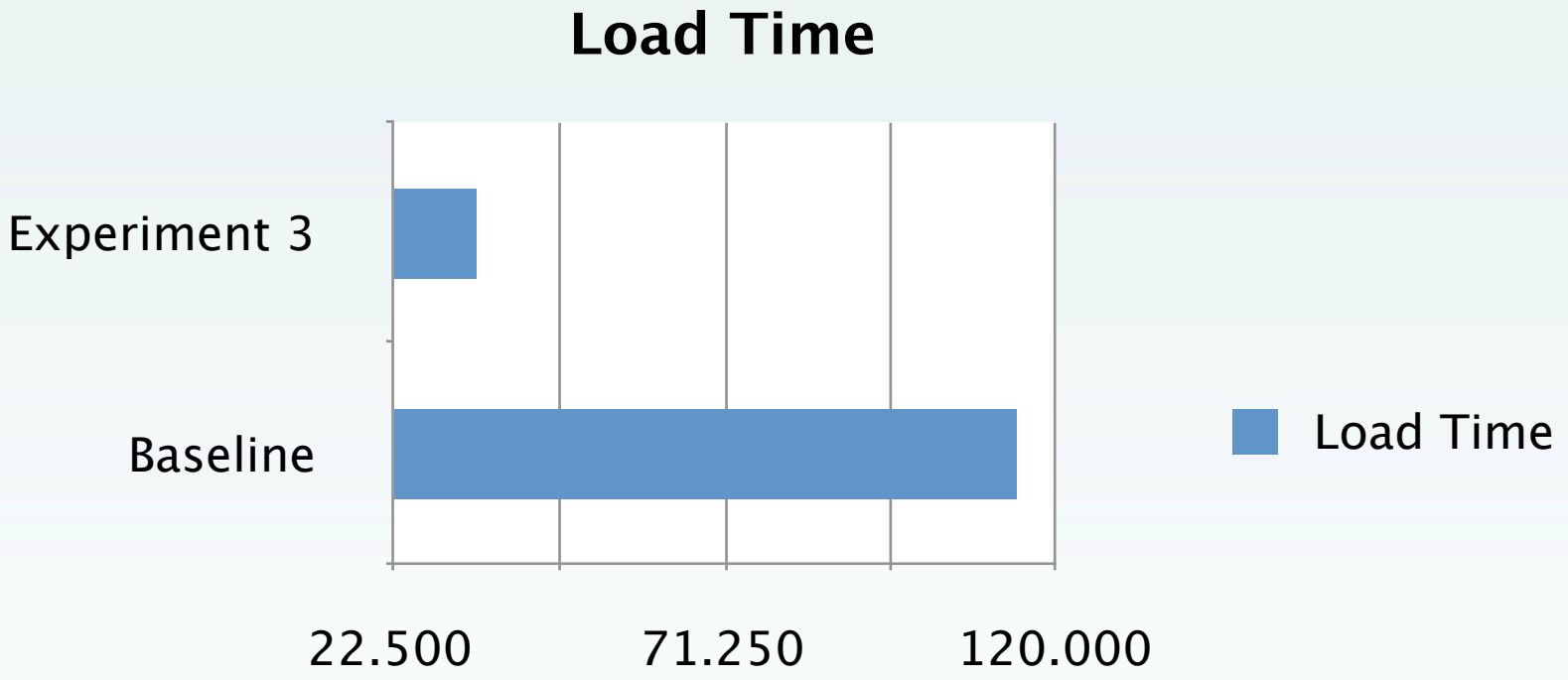
Putting it All Together



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Putting it All Together

- Final overall load time using 5 drones, along with threaded http calls for loadFund, saw overall load time improve from 114 seconds to 35 Seconds
  - The 35 seconds *includes* all image startup and transport time

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Some Observations

- Measure the elapsed time of work - it helps to know where the problems are in order to address them
- There are multiple way to do concurrency. In one experiment, I backed off using the new framework, because a simpler approach worked better. This was a pleasant surprise - the green thread model was actually very well suited for that problem. I ended up combining both for a superior solution.
- Strive for simplicity. Remember if it gets out of hand, concurrency can get ugly and difficult very quickly. Follow the KISS principle (Keep it Simple, Smalltalk ;-)).

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Some Observations

- The launch of drone images was faster than I expected
- Drone images are instances of the main image
- As mentioned in the commentary, my measurements included startup and shutdown of images, a (overly?) conservative approach that may be atypical to how many use this technology. Results would be even better had I not included that.

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Some Observations

- The experimental work has some pieces that I think show a lot of foresight. Mechanisms for handling some common issues. Like what?
  - If I had a dozen drone images running and lost my references and the ability to close them, closing the main image shuts everything down. Things like that save a lot of time, avoid aggravation, and make it fun.
  - If I started a local process, which in turn started a drone, then later I terminated that process, the drone would be terminated.
  - Remote errors can be retrieved locally

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Conclusions

- I believe my requirements of providing one means of concurrency with maximum gain and minimum pain are met
- My expectations on the simplicity and robustness of the experimental framework were surpassed

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