# “KAVERI” AND THE HSA ADVANTAGE

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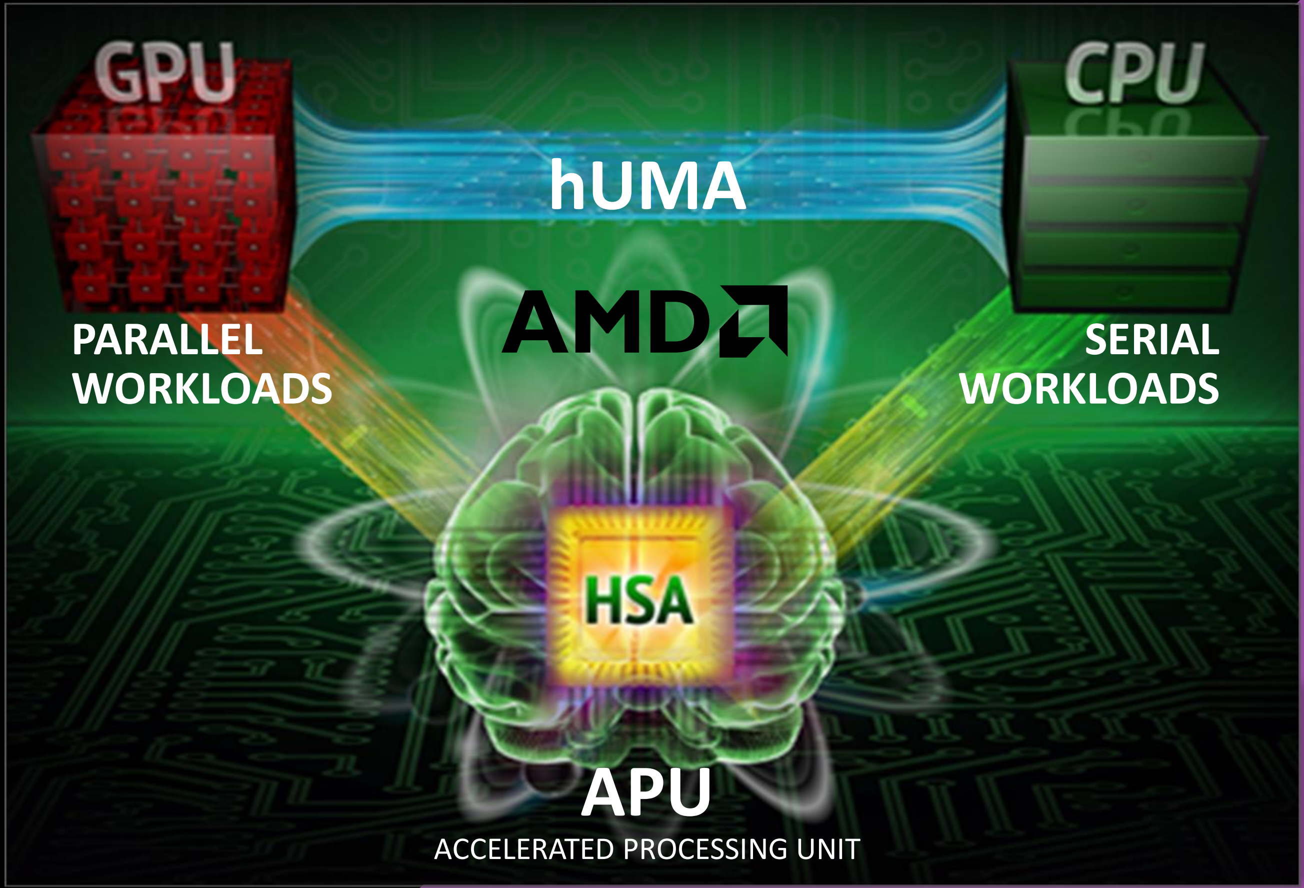
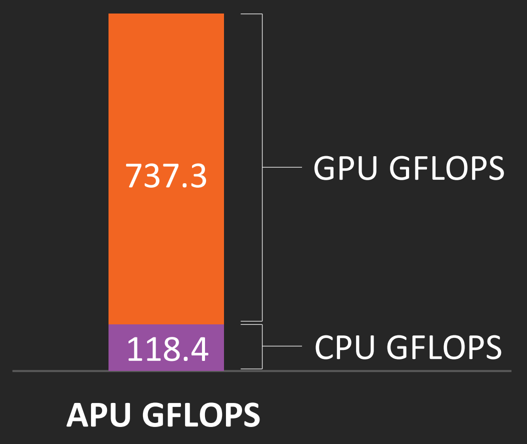
# WHAT IS HSA?




**Processor design** that makes it easy to harness the **entire computing power of an APU** for faster and more power-efficient devices, including personal computers, tablets, smartphones and cloud servers

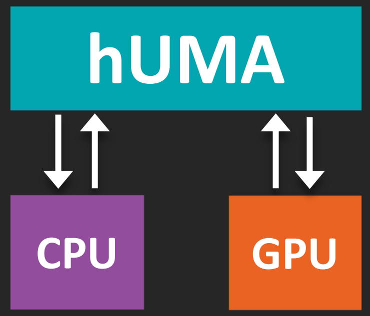
# HSA FEATURES OF "KAVERI"

## UNLOCKING All OF KAVERI'S GFLOPS



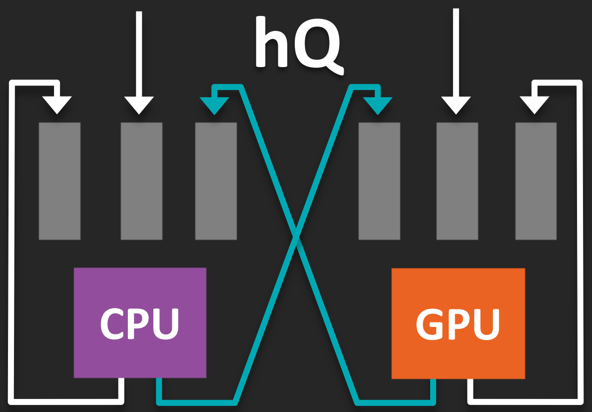

- Access to full potential of Kaveri's APU compute power

## EQUAL ACCESS TO ENTIRE MEMORY




- GPU and CPU have uniform visibility into entire memory space

## ALL-PROCESSORS-EQUAL




- GPU and CPU have equal flexibility to be used to create and dispatch work items

# OPENCL™ 2.0 FEATURES AND HSA

AMD

- Some of the key features of OpenCL 2.0 and their HSA mapping

| OpenCL 2.0 Feature | HSA Mapping |
|---|---|
| Shared Virtual Memory | hUMA |
| Dynamic Parallelism | hQ |
| Pipes | hUMA, hQ |
| C11 Atomics | Platform Atomics |

# HSA ADVANTAGES OF "KAVERI"

- HSA features make "Kaveri" the FIRST full OpenCL 2.0 capable chip
- Ease of programming to use the GPU for compute
- Easy access to up to 12 Compute Cores*
- More applications from ease of use
- Better user experiences

*for more information on Compute Cores please visit AMD.com/computecores

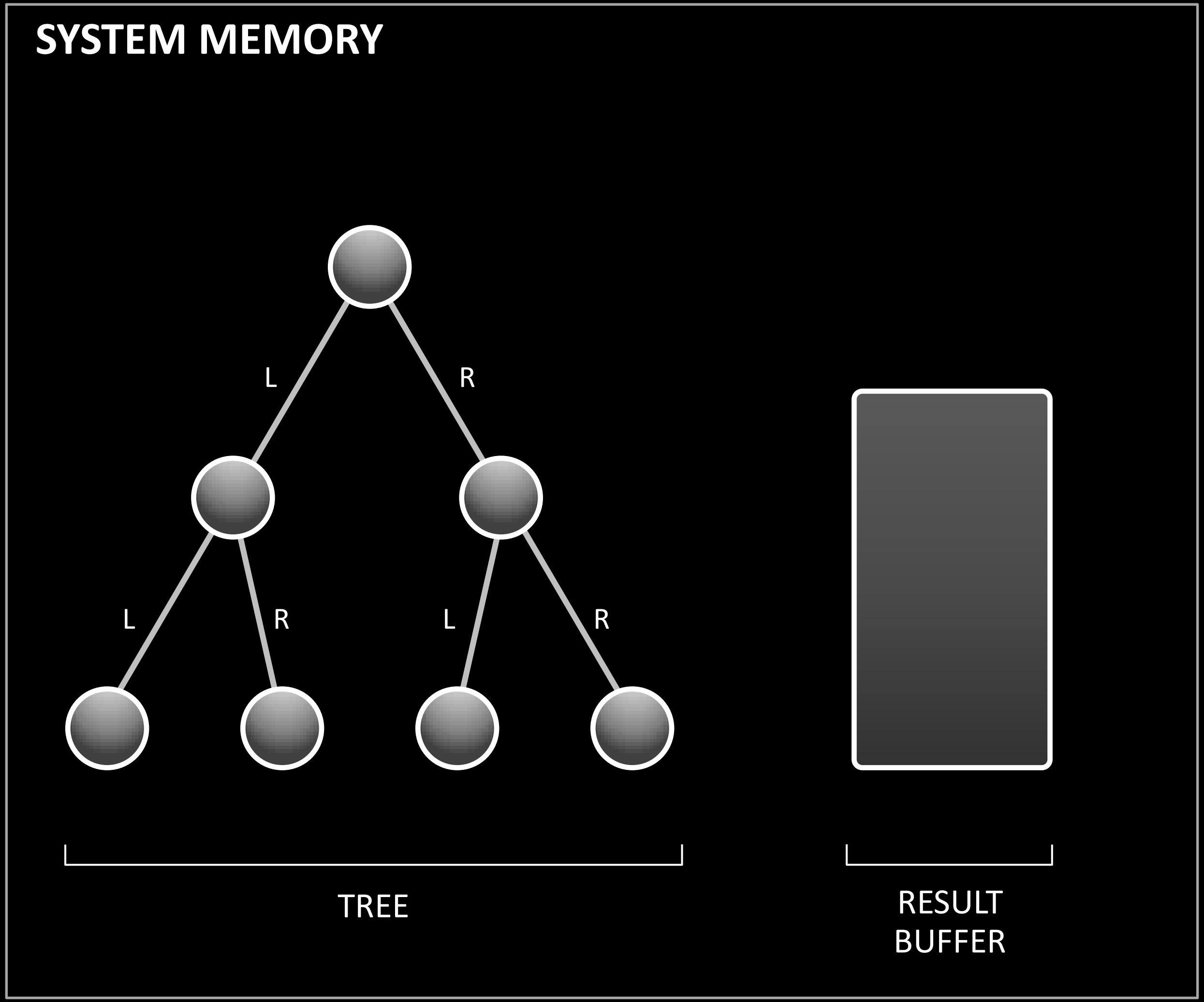
# USE CASES SHOWING HSA ADVANTAGE

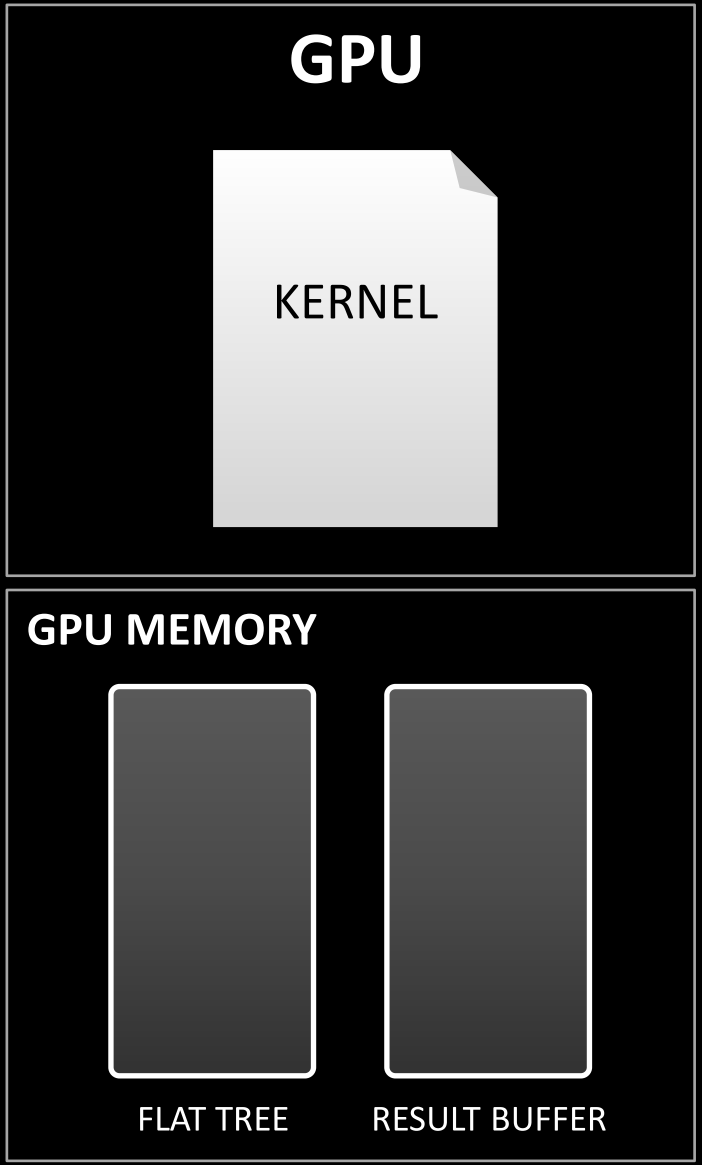
| Programming Technique | Use Case Description | HSA Advantage |
|---|---|---|
| **Data Pointers** | **Binary tree searches**<br>GPU performs searches in a CPU created binary tree | GPU can access existing data structures containing pointers<br>Higher performance through parallel operations |
| **Platform Atomics** | **Binary tree updates**<br>CPU and GPU operating simultaneously on the tree, both doing modifications | CPU and GPU can synchronize using Platform Atomics<br>Higher performance through parallel operations |
| **Large Data Sets** | **Hierarchical data searches**<br>Applications include object recognition, collision detection, global illumination, BVH | GPU can operate on huge models in place<br>Higher performance through parallel operations |
| **CPU Callbacks** | **Middleware user-callbacks**<br>GPU processes work items, some of which require a call to a CPU function to fetch new data | GPU can invoke CPU functions from within a GPU kernel<br>Simpler programming does not require “split kernels”<br>Higher performance through parallel operations |

# Data Pointers

# DATA POINTERS

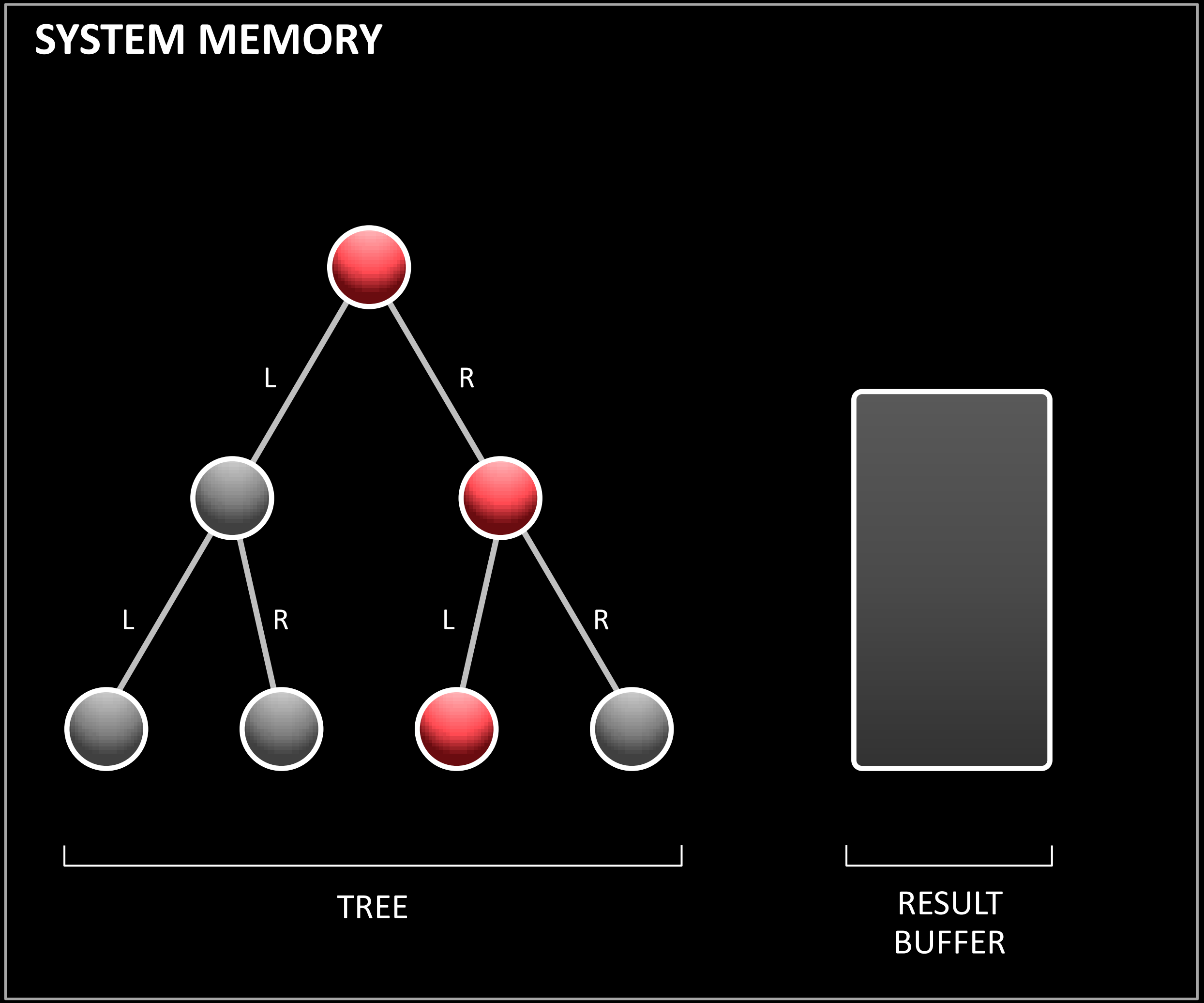
Legacy

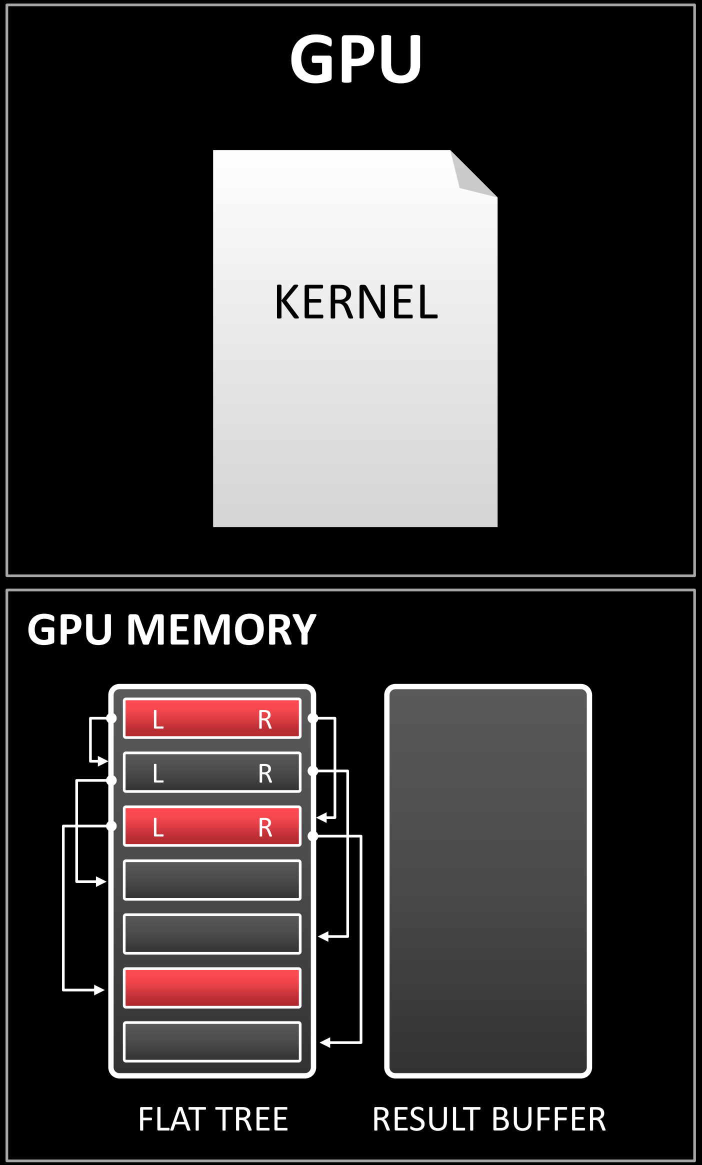


# DATA POINTERS

Legacy



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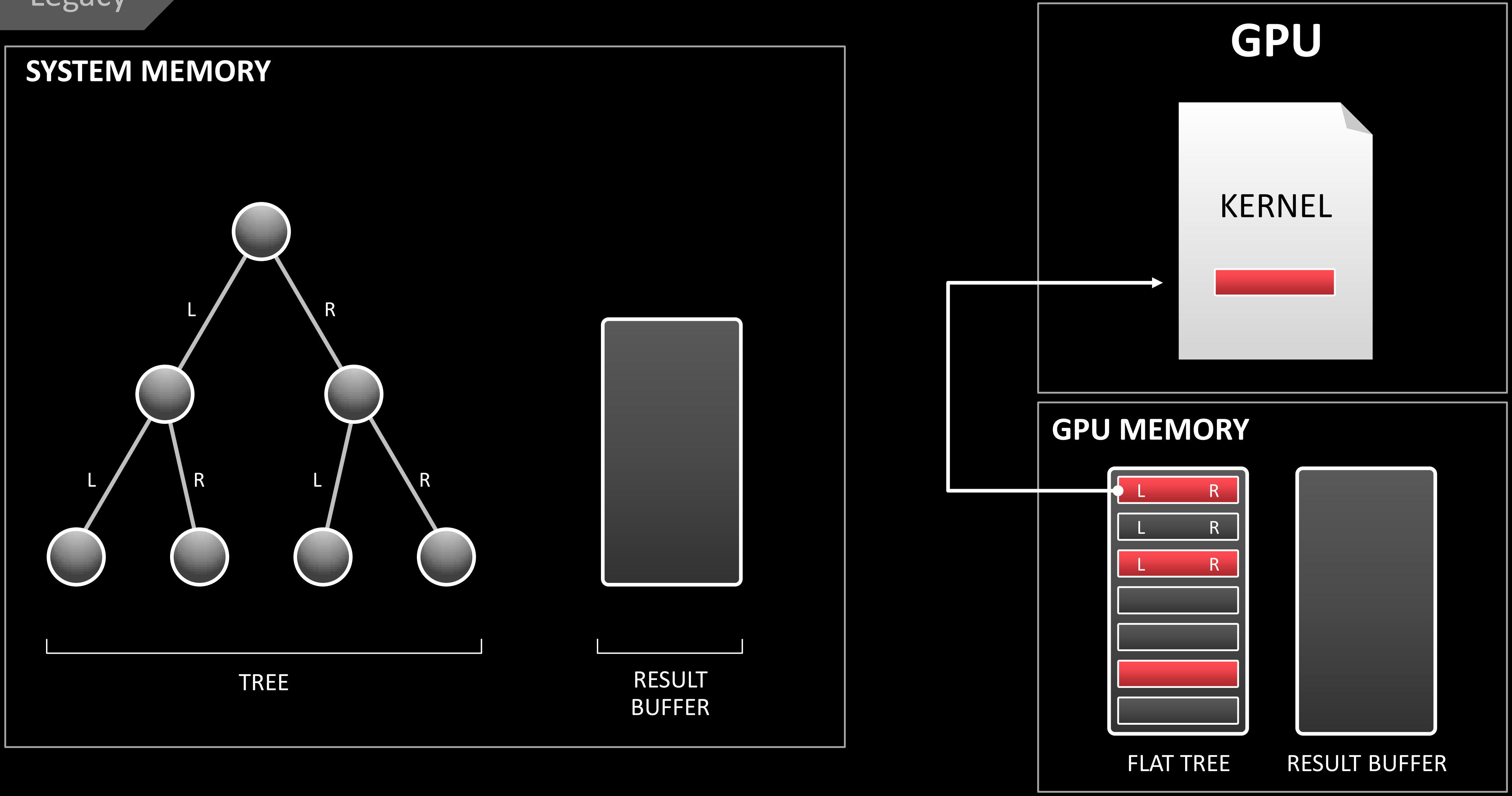

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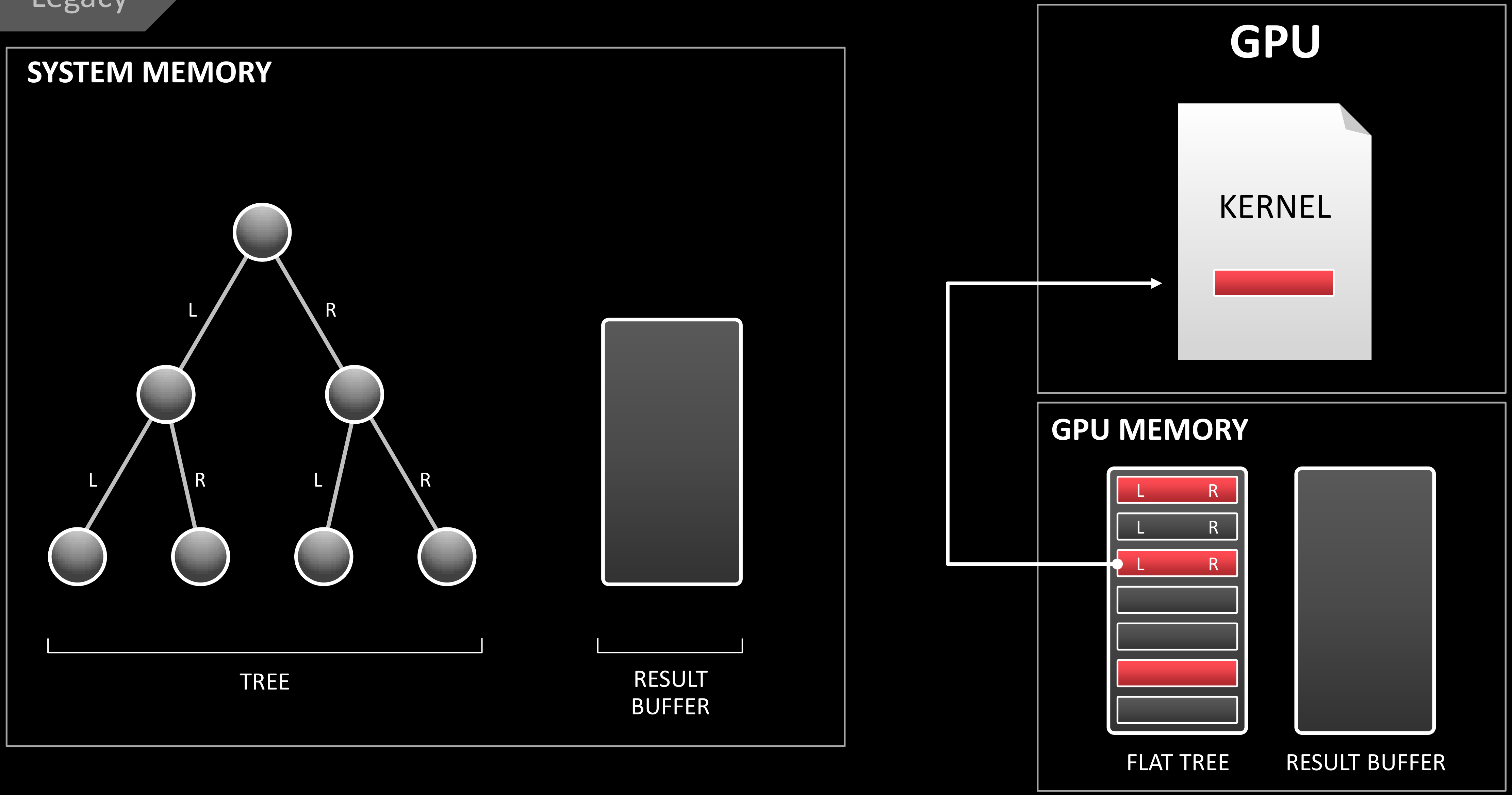

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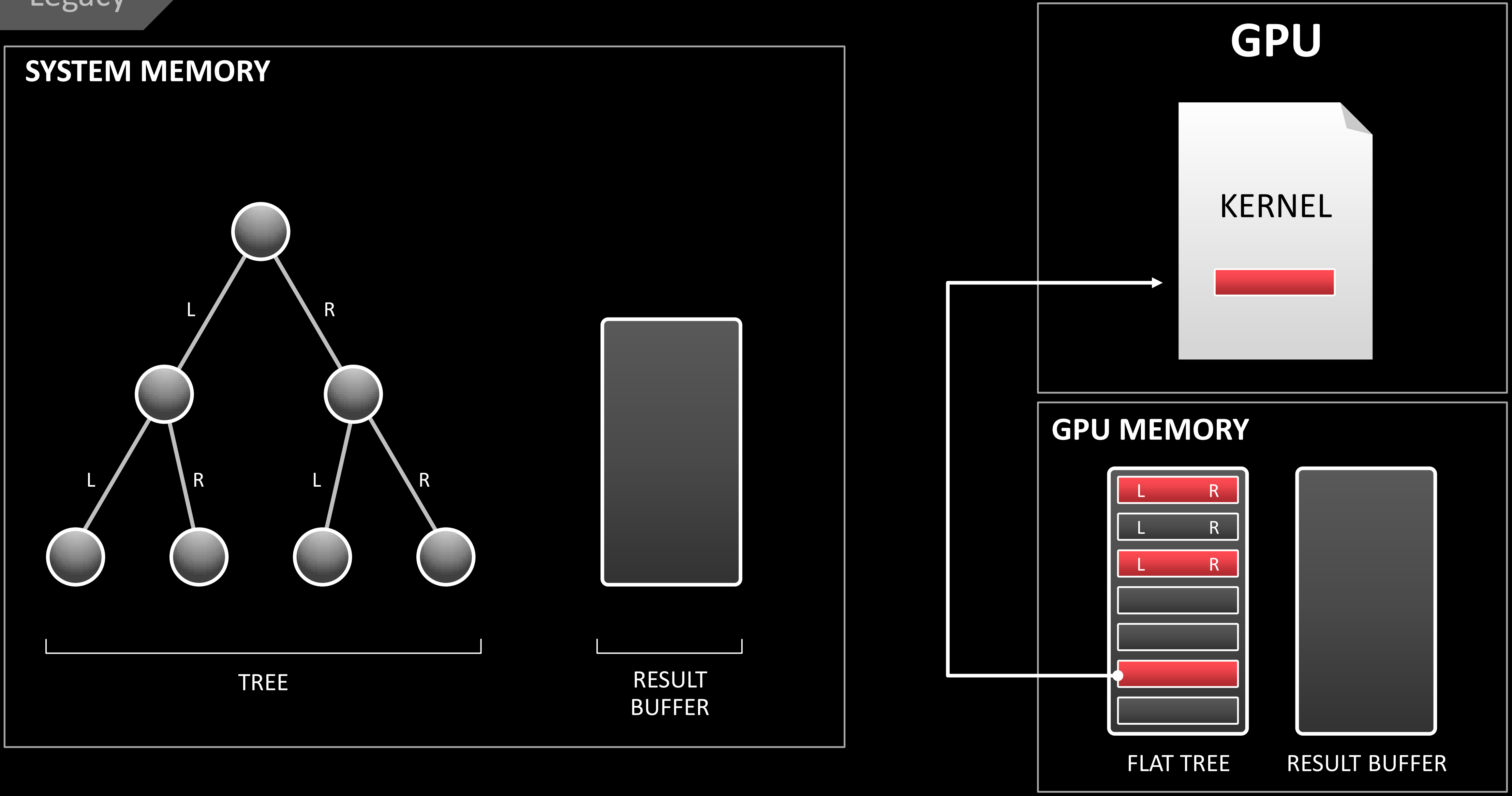
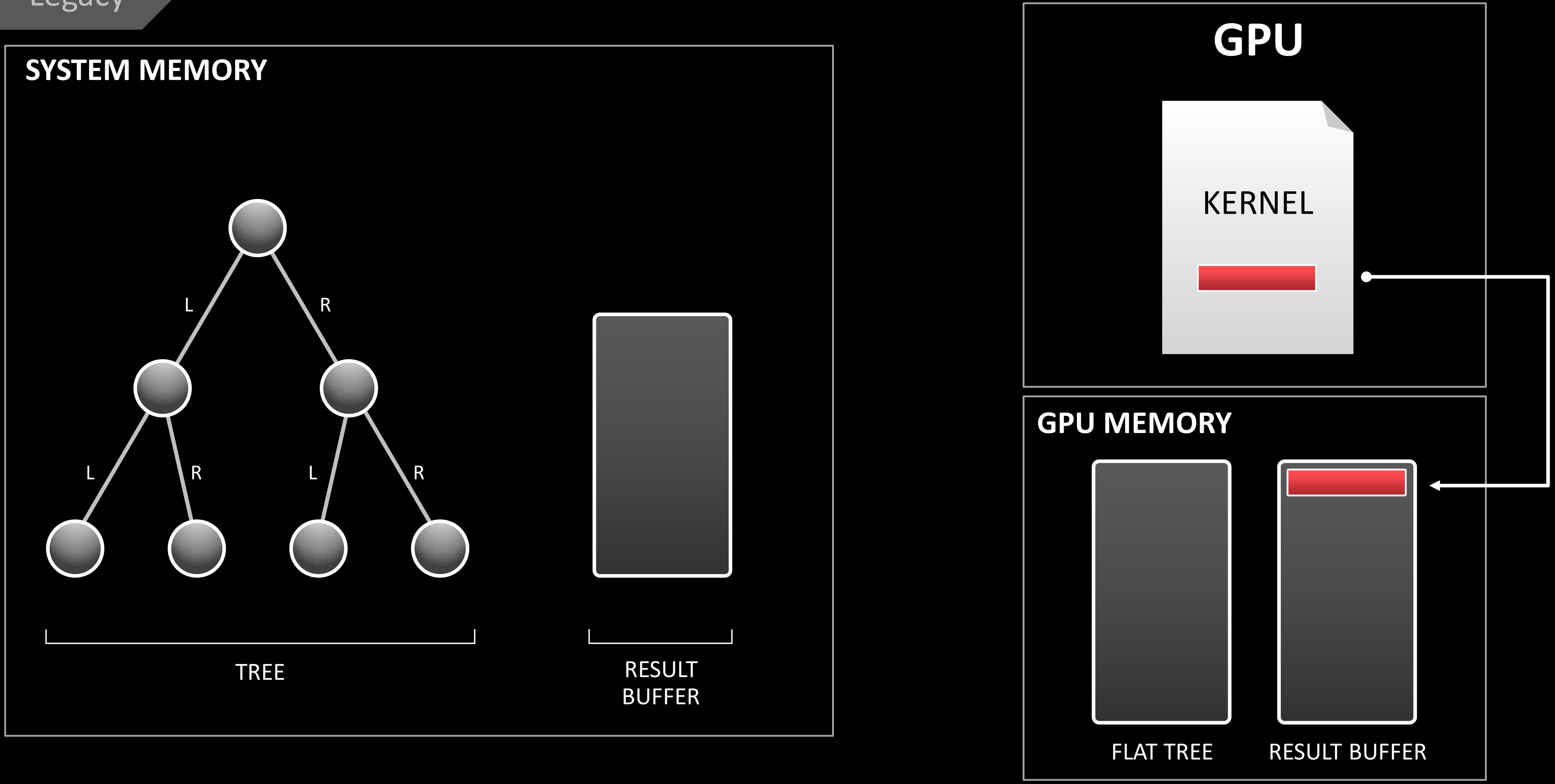


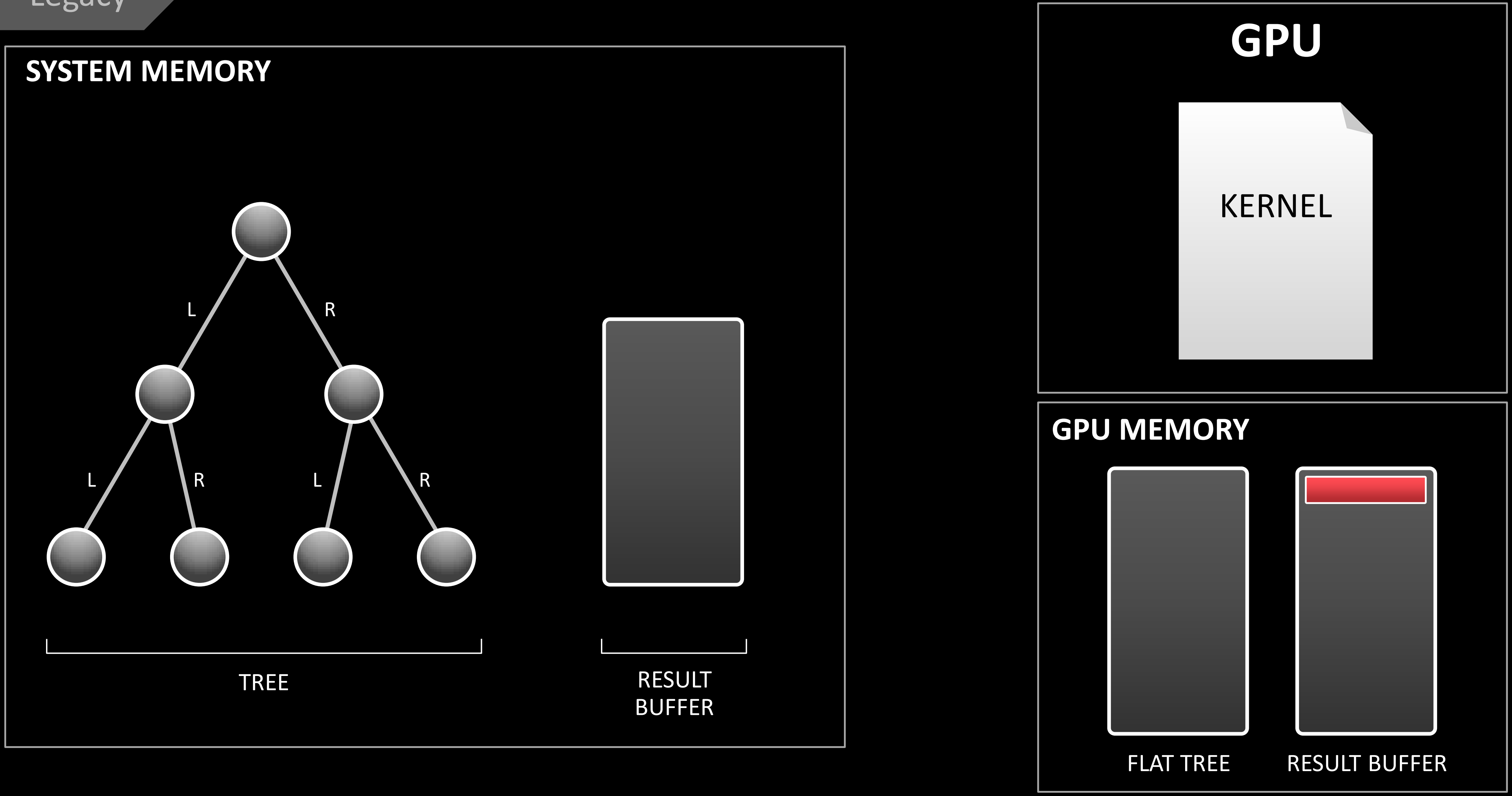
# DATA POINTERS

Legacy



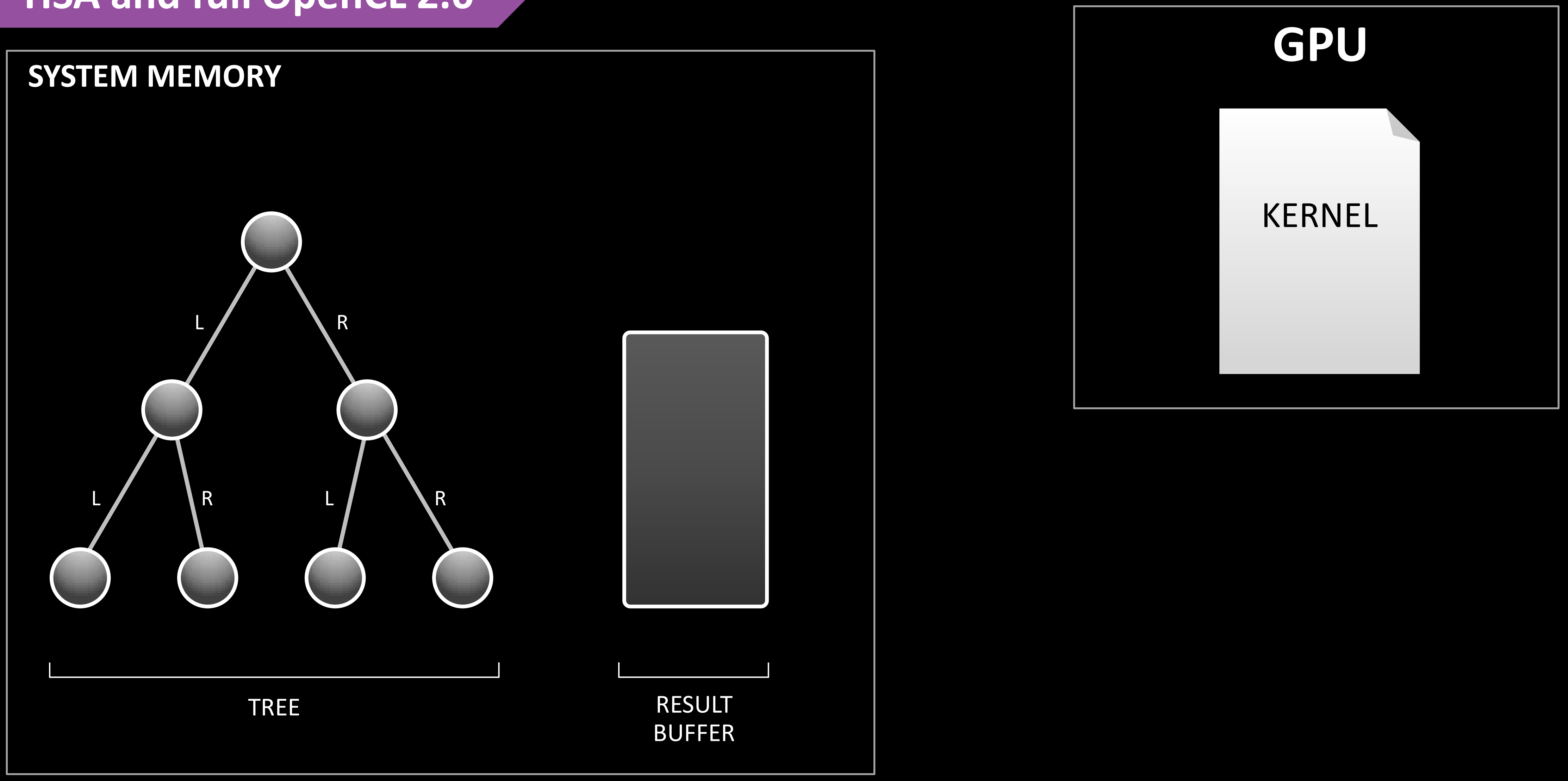
# DATA POINTERS

## Legacy



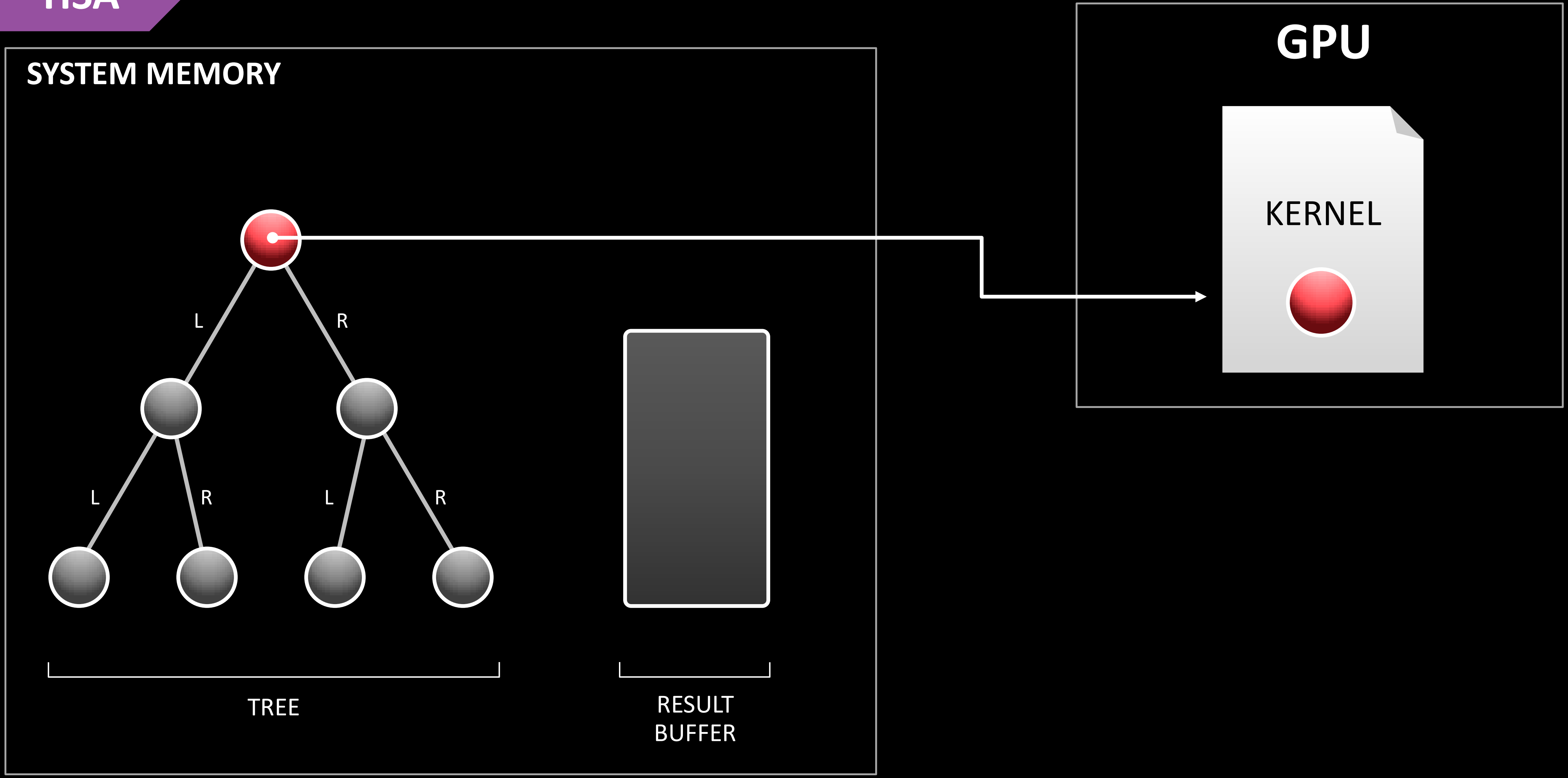
# DATA POINTERS

## HSA and full OpenCL 2.0



# DATA POINTERS

## HSA



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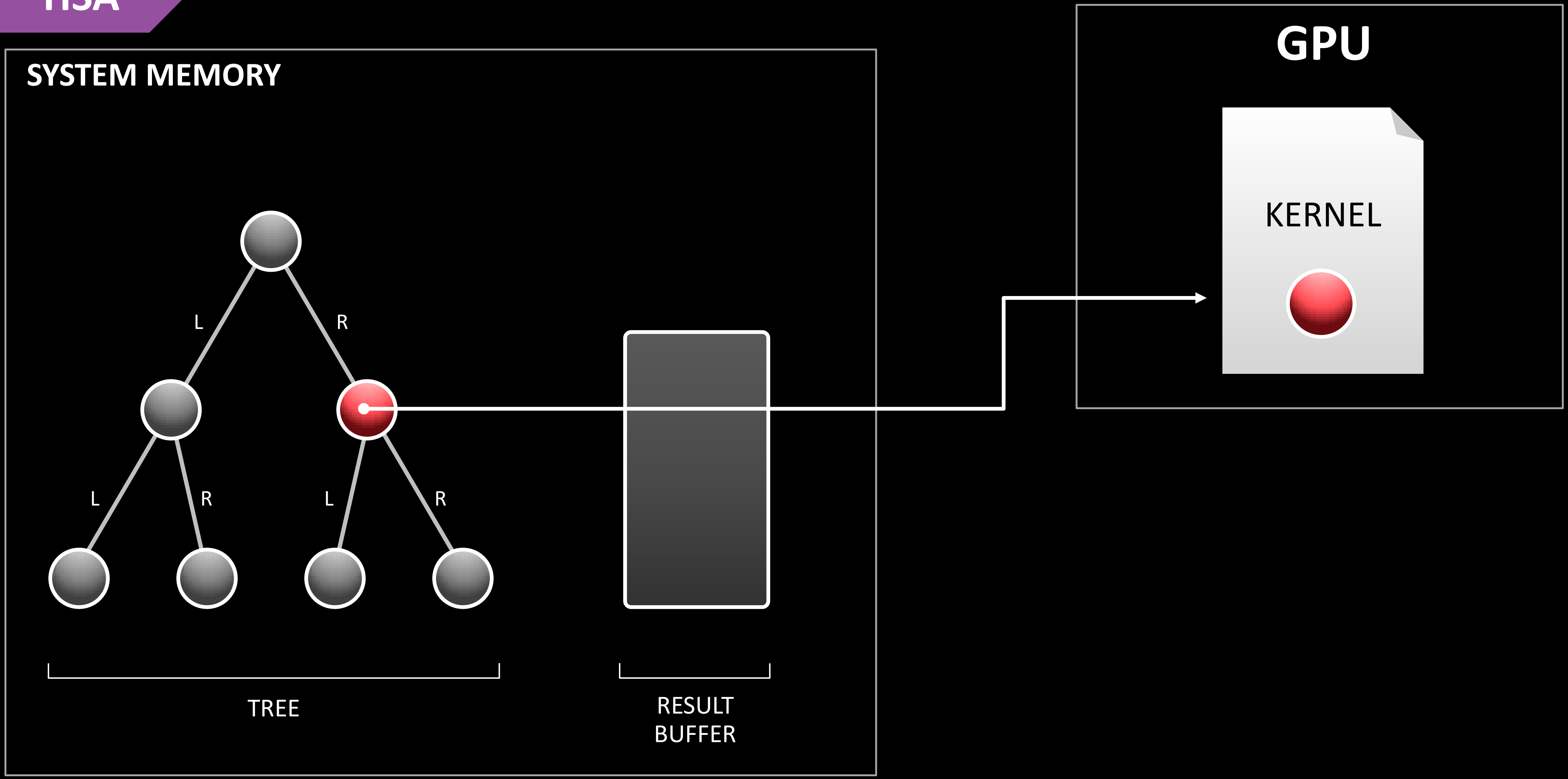
**HSA**



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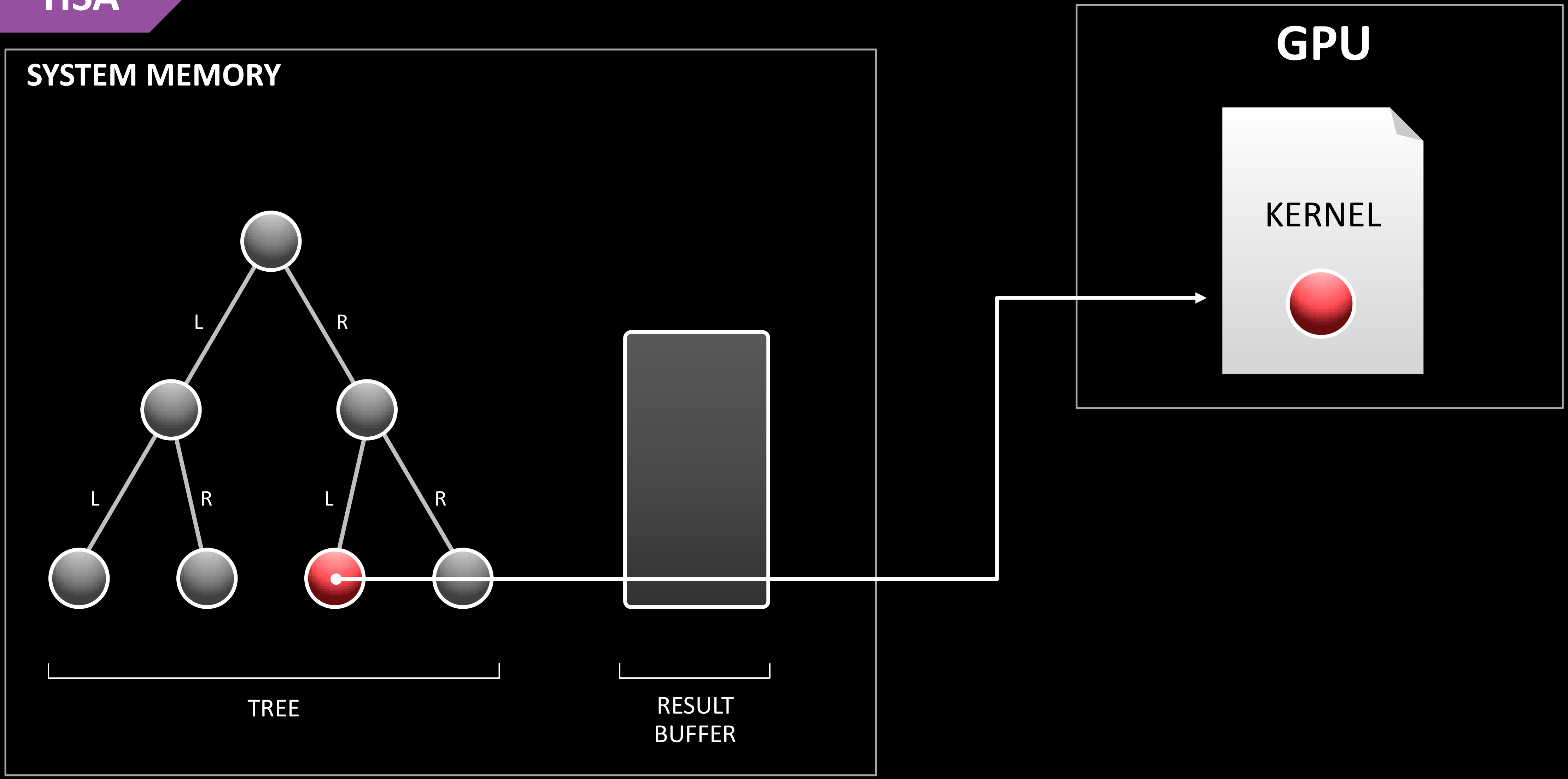
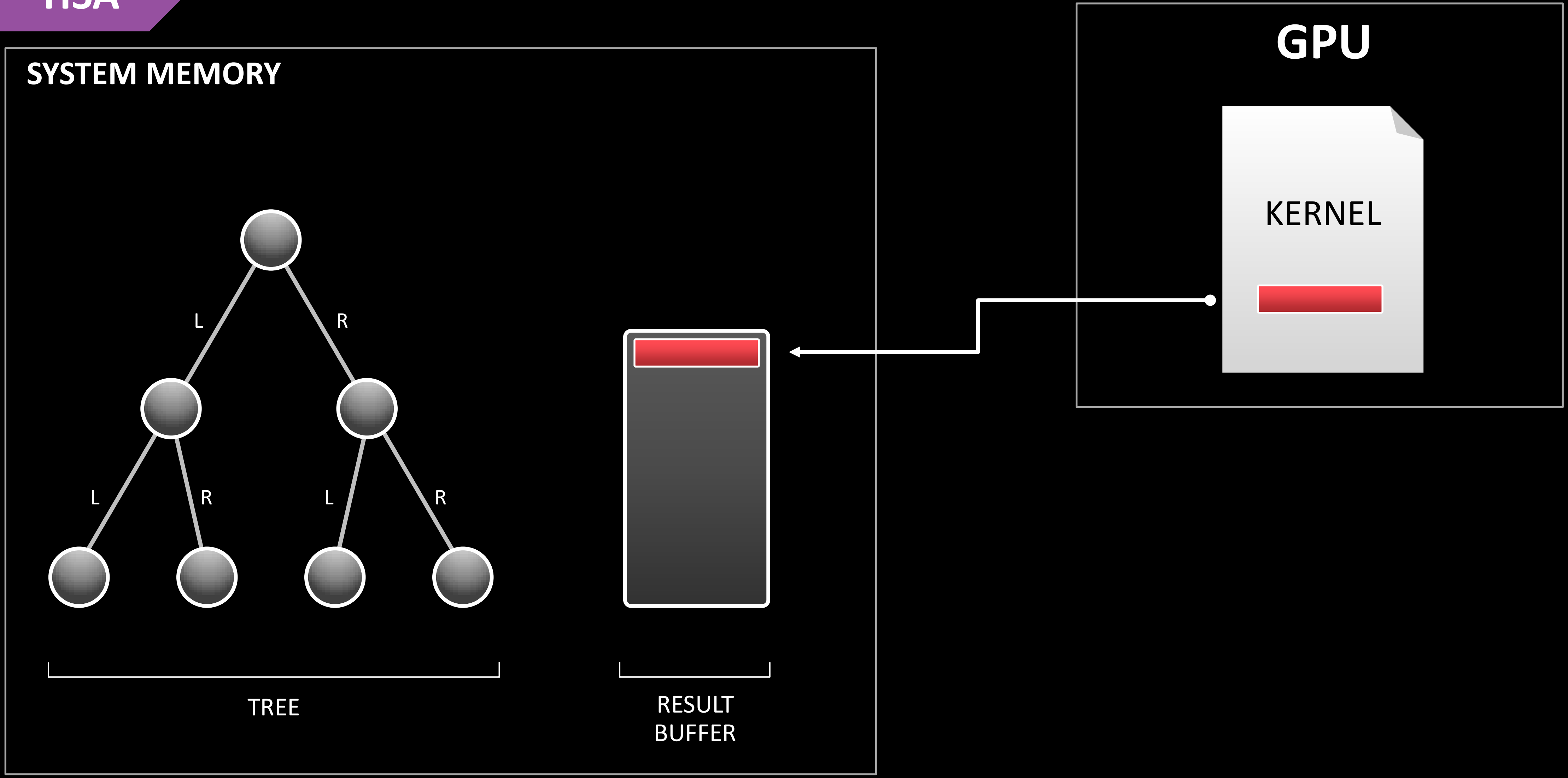
## HSA



# DATA POINTERS

**HSA**



# DATA POINTERS - CODE COMPLEXITY

AMD

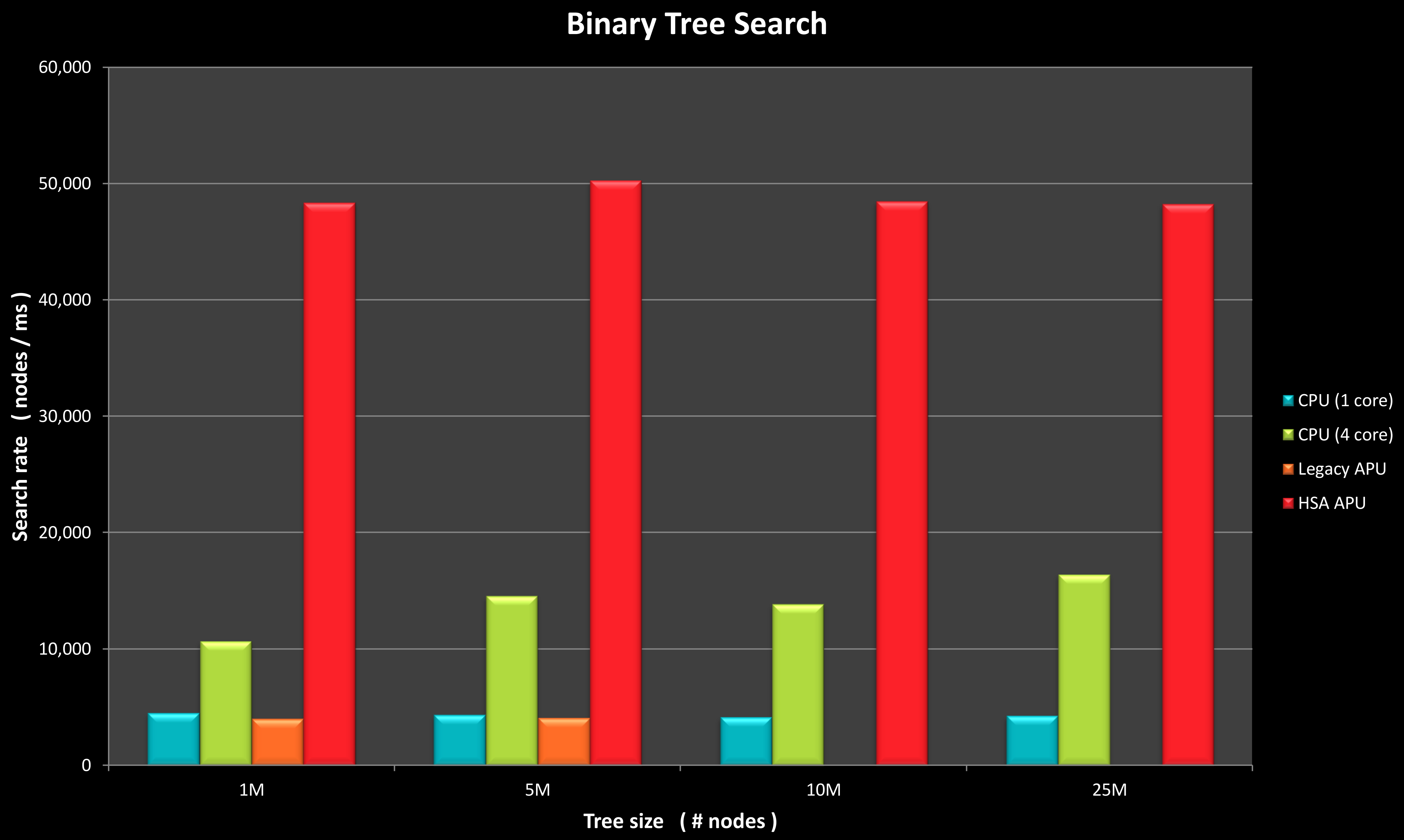
HSA

```
static void run_hsa_path()
{
    /* Allocation and initialization */
    tree = (node *) clSVMAlloc(context, CL_MEM_READ_ONLY,
            num_nodes * sizeof(node), 0);
    initialize_nodes(tree, num_nodes);
    root = construct_BST(num_nodes, tree);

    search_keys = (int *) clSVMAlloc(context, CL_MEM_READ_ONLY,
            num_search_keys * sizeof(int), 0);
    initialize_search_keys(search_keys, num_search_keys, sort_input);

    found_key_nodes = (node **) clSVMAlloc(context, CL_MEM_WRITE_ONLY,
            num_search_keys * sizeof(node *), 0);
    memset(found_key_nodes, 0, num_search_keys * sizeof(node *));

    /* GPU work enqueue */
    clSetKernelArgSVMPointer(search_kernel, 0, root);
    clSetKernelArgSVMPointer(search_kernel, 1, search_keys);
    clSetKernelArgSVMPointer(search_kernel, 2, &num_search_keys);
    clSetKernelArgSVMPointer(search_kernel, 3, found_key_nodes);

    clEnqueueNDRangeKernel(queue, search_kernel, 1, NULL,
            &num_search_keys, &preferredLocalSize, 0, NULL, &kernel_event);

    clFinish(queue);

    /* Cleanup */
    clSVMFree(context, tree);
    clSVMFree(context, found_key_nodes);
    clSVMFree(context, search_keys);
}
```

Legacy

```
static void run_ocl_path()
{
    /* Allocation and initialization */
    tree = (node *) malloc(num_nodes * sizeof(node));
    initialize_nodes(tree, num_nodes);
    root = construct_BST(num_nodes, tree);

    search_keys = (int *) malloc(num_search_keys * sizeof(int));
    initialize_search_keys(search_keys, num_search_keys, sort_input);

    found_keys = (int *) malloc(num_search_keys * sizeof(int));
    memset(found_keys, 0, num_search_keys * sizeof(int));

    ocl_tree = (ocl_node *) malloc(num_nodes * sizeof(ocl_node));

    cl_mem cl_ocl_tree = clCreateBuffer(context, CL_MEM_READ_ONLY,
            num_nodes * sizeof(ocl_node), NULL, &status);
    cl_mem cl_search_keys = clCreateBuffer(context, CL_MEM_READ_ONLY,
            num_search_keys * sizeof(int), NULL, &status);
    cl_mem cl_found_nodes_id = clCreateBuffer(context, CL_MEM_WRITE_ONLY,
            num_search_keys * sizeof(int), NULL, &status);

    /* The tree is converted to its array form */
    int root_id;
    initialize_ocl_nodes(ocl_tree, num_nodes);
    convert_tree_to_array(root, ocl_tree, &root_id);

    /* Copy the tree and search keys array to the GPU */
    clEnqueueWriteBuffer(queue, cl_ocl_tree, CL_TRUE, 0,
            num_nodes * sizeof(ocl_node), ocl_tree, 0, NULL, NULL);

    clEnqueueWriteBuffer(queue, cl_search_keys, CL_TRUE, 0,
            num_search_keys * sizeof(int), search_keys, 0, NULL, NULL);

    /* GPU work enqueue */
    clSetKernelArg(search_kernel, 0, sizeof(cl_ocl_tree), &cl_ocl_tree);
    clSetKernelArg(search_kernel, 1, sizeof(cl_int), &root_id);
    clSetKernelArg(search_kernel, 2, sizeof(cl_search_keys), &cl_search_keys);
    clSetKernelArg(search_kernel, 3, sizeof(cl_int), &num_search_keys);
    clSetKernelArg(search_kernel, 4, sizeof(cl_found_nodes_id), &cl_found_nodes_id);

    clEnqueueNDRangeKernel(queue, search_kernel, 1, NULL,
            &num_search_keys, &preferredLocalSize, 0, NULL, NULL);

    clFinish(queue);

    /* Copy the results back from the GPU */
    clEnqueueReadBuffer(queue, cl_found_nodes_id, CL_TRUE, 0,
            num_search_keys * sizeof(int), found_keys, 0, NULL, NULL);

    /* Cleanup */
    free(ocl_tree);
    free(tree);
    free(found_keys);
    free(search_keys);

    clReleaseMemObject(cl_ocl_tree);
    clReleaseMemObject(cl_search_keys);
    clReleaseMemObject(cl_found_nodes_id);
}


static void initialize_ocl_nodes(ocl_node *ocl_tree, long long int num_nodes)
{
    for (int i = 0; i < num_nodes; i++) {
        ocl_tree[i].left = -1;
        ocl_tree[i].right = -1;
    }
}


static void convert_tree_to_array(node *root, ocl_node *ocl_tree, int *root_id)
{
    node **tree_queue;
    node *tmp;

    tree_queue = (node **)calloc(num_nodes, sizeof(node *));

    long long int front = 0;
    long long int rear  = 0;

    tree_queue[rear] = root;
    ocl_tree[rear].value = root->value;
    rear++;

    *root_id = 0;

    while (front != rear) {
        tmp = tree_queue[front];
        if (!tmp)
            break;

        if (tmp->left) {
            tree_queue[rear] = tmp->left;
            ocl_tree[rear].value = tmp->left->value;
            ocl_tree[front].left = (int)rear;
            rear++;
        }

        if (tmp->right) {
            tree_queue[rear] = tmp->right;
            ocl_tree[rear].value = tmp->right->value;
            ocl_tree[front].right = (int)rear;
            rear++;
        }

        front++;
    }

    if (tree_queue)
        free(tree_queue);
}
```

# DATA POINTERS - PERFORMANCE




Measured in AMD labs Jan 1-3 on system shown in back up slide

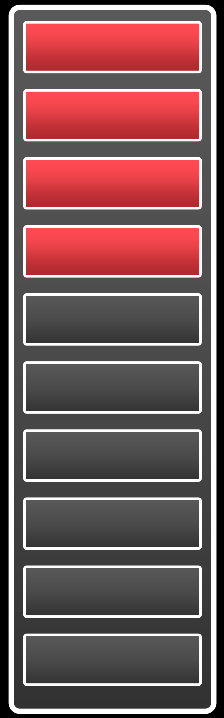
# Platform Atomics

# PLATFORM ATOMICS

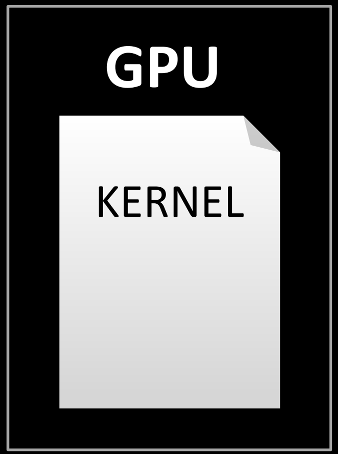
Legacy

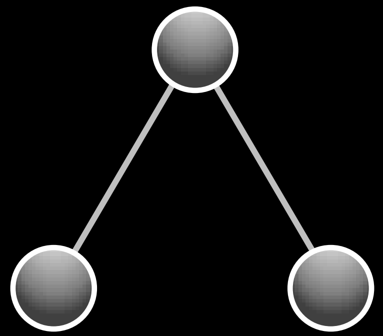
Only GPU can work on input array

**Concurrent processing not possible**



INPUT BUFFER



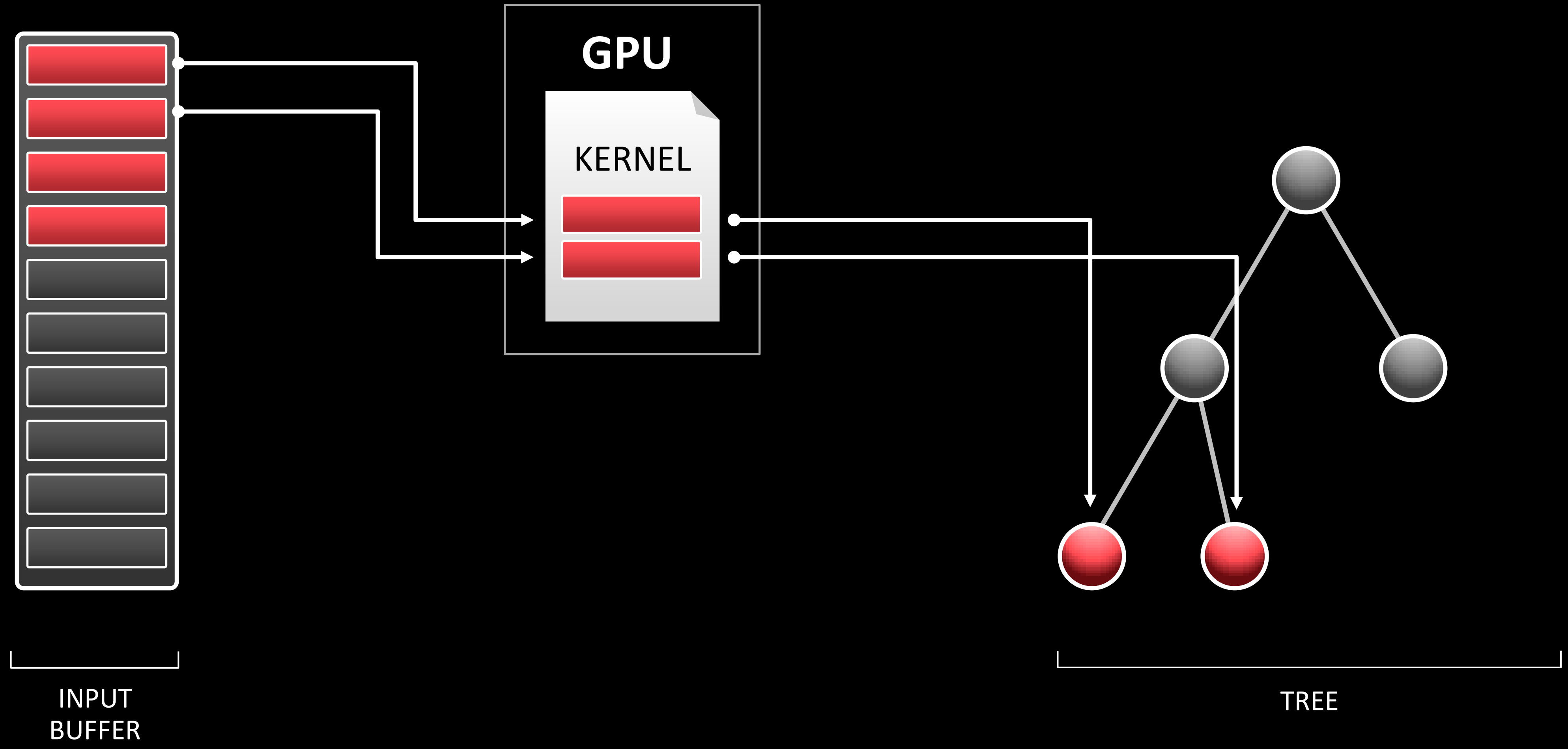
TREE

# PLATFORM ATOMICS

Legacy

Only GPU can work on input array

**Concurrent processing not possible**



# PLATFORM ATOMICS

Legacy

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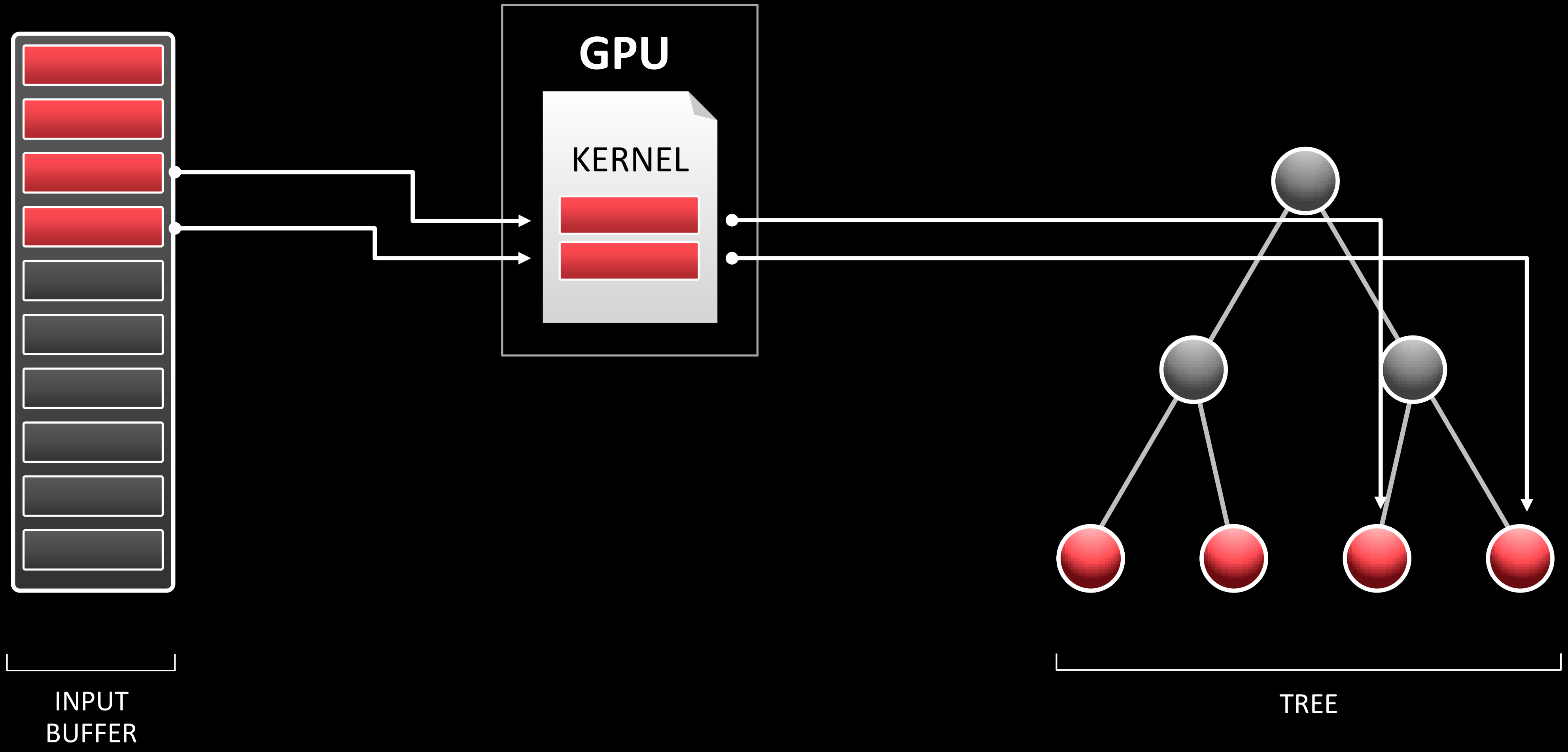
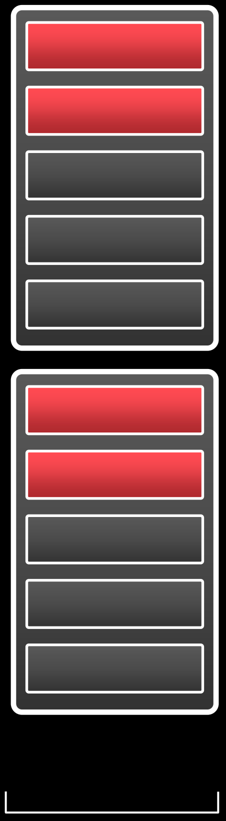


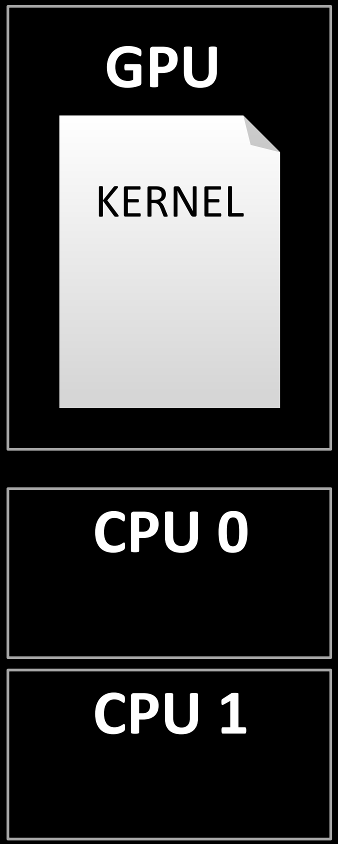
# PLATFORM ATOMICS

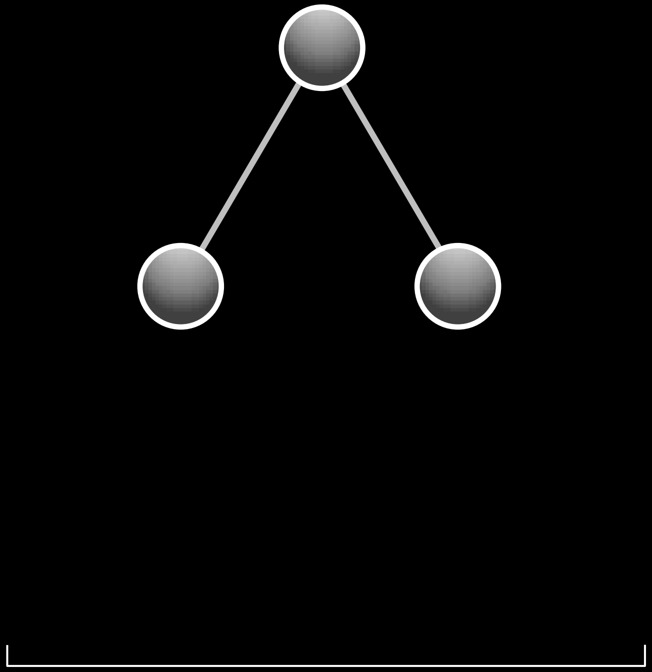
## HSA and full OpenCL 2.0

Both
CPU+GPU
operating on
same data
structure
**concurrently**



INPUT
BUFFER



TREE

# PLATFORM ATOMICS

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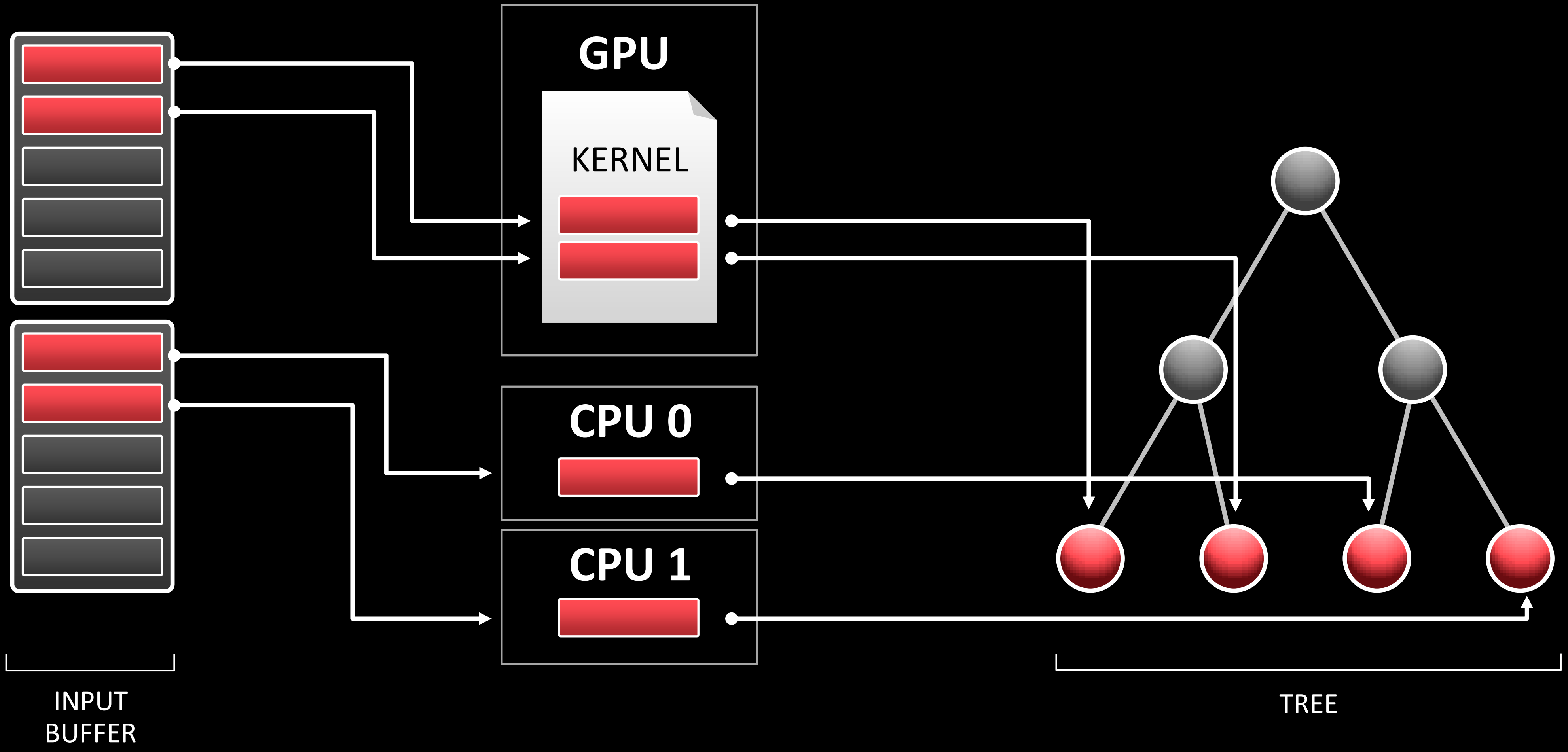


# Large
# Data Sets

# PROCESSING LARGE DATA SETS

AMD

**SYSTEM MEMORY**

**GPU**

The CPU creates a large data structure in System Memory. Computations using the data are offloaded to the GPU.

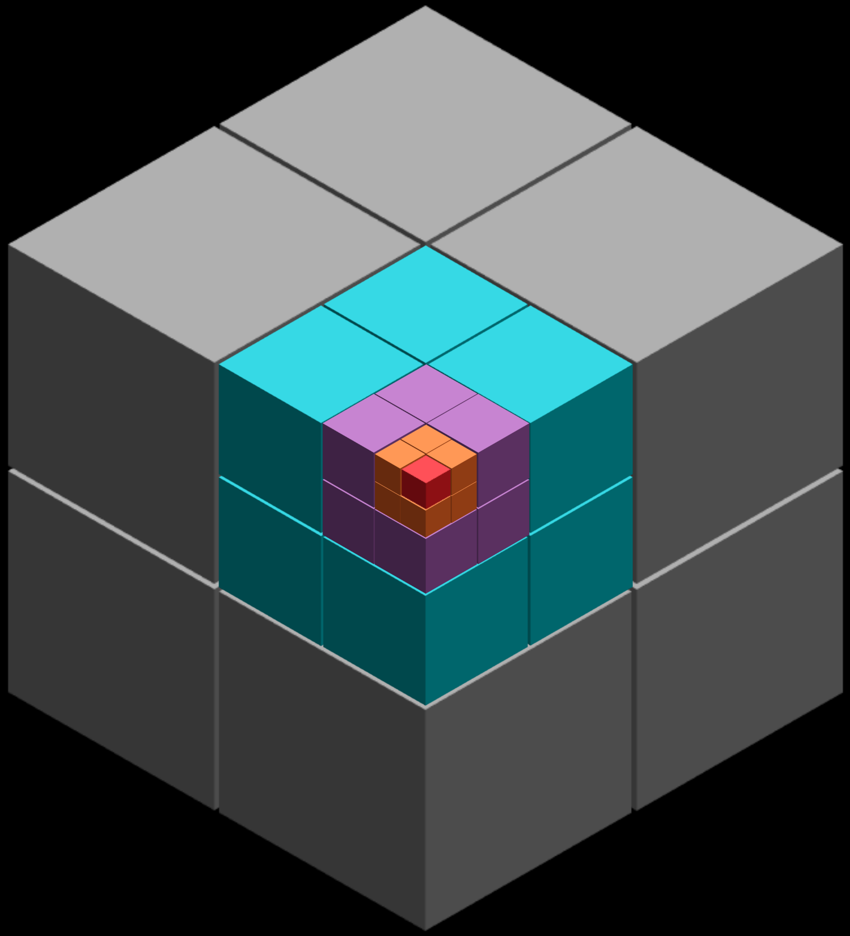
# PROCESSING LARGE DATA SETS

Level 1 Level 2 Level 3 Level 4 Level 5

AMD

**SYSTEM MEMORY**

Large 3D spatial data structure



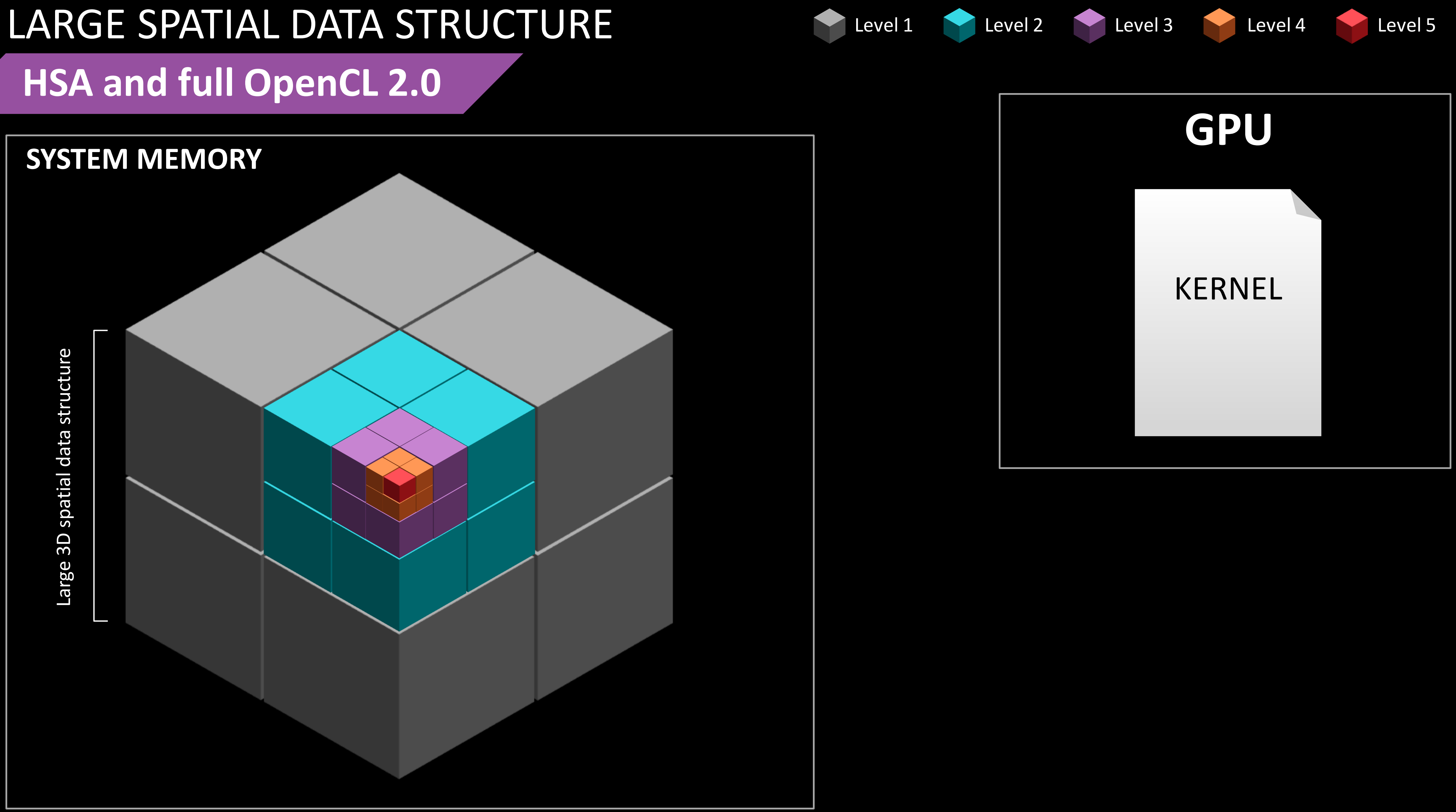
**GPU**

The CPU creates a large data structure in System Memory. Computations using the data are offloaded to the GPU.

Compare HSA and Legacy methods

# LARGE SPATIAL DATA STRUCTURE

## HSA and full OpenCL 2.0

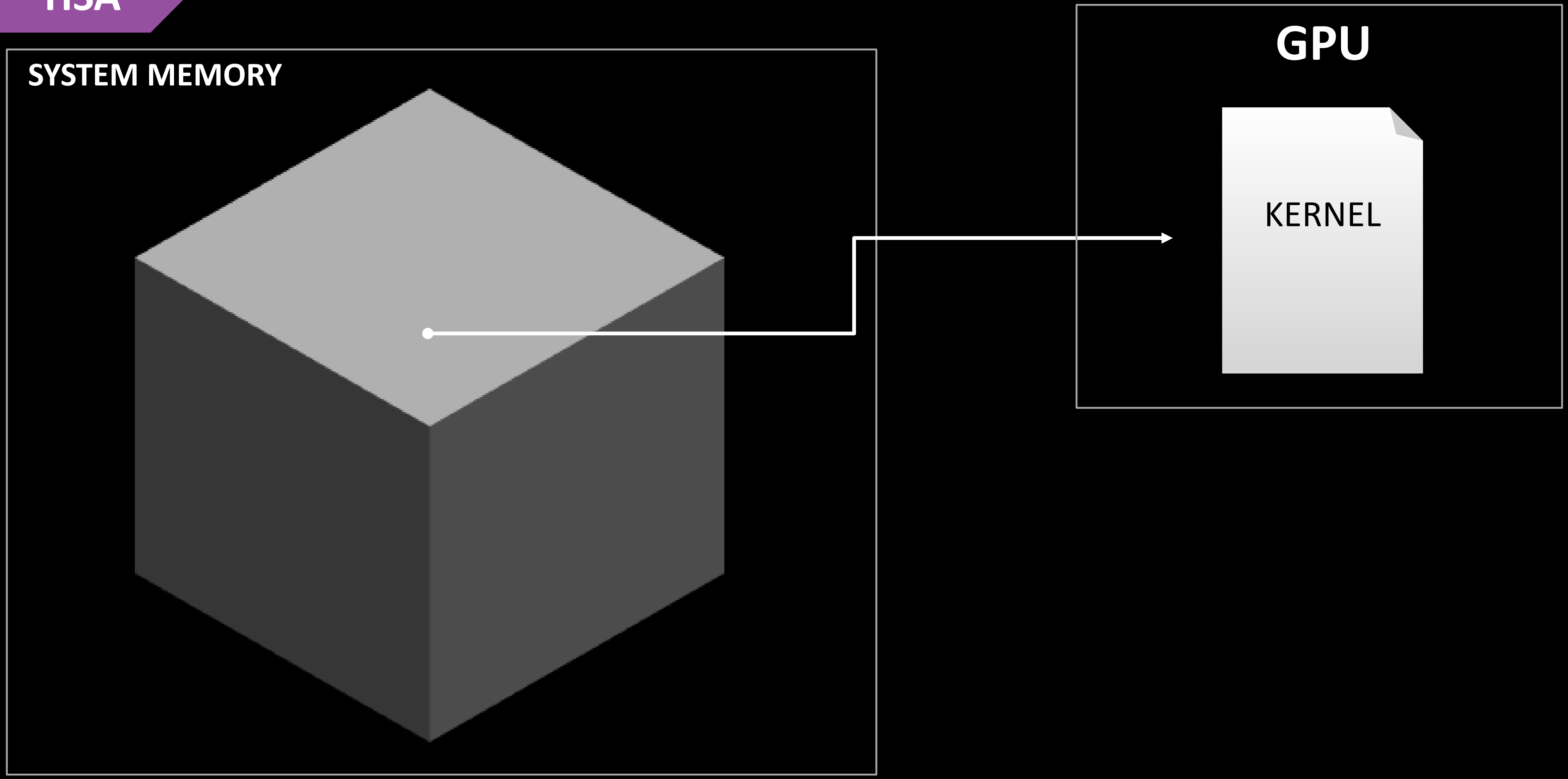


# GPU CAN TRAVERSE ENTIRE HIERARCHY

Level 1 Level 2 Level 3 Level 4 Level 5

AMD

HSA



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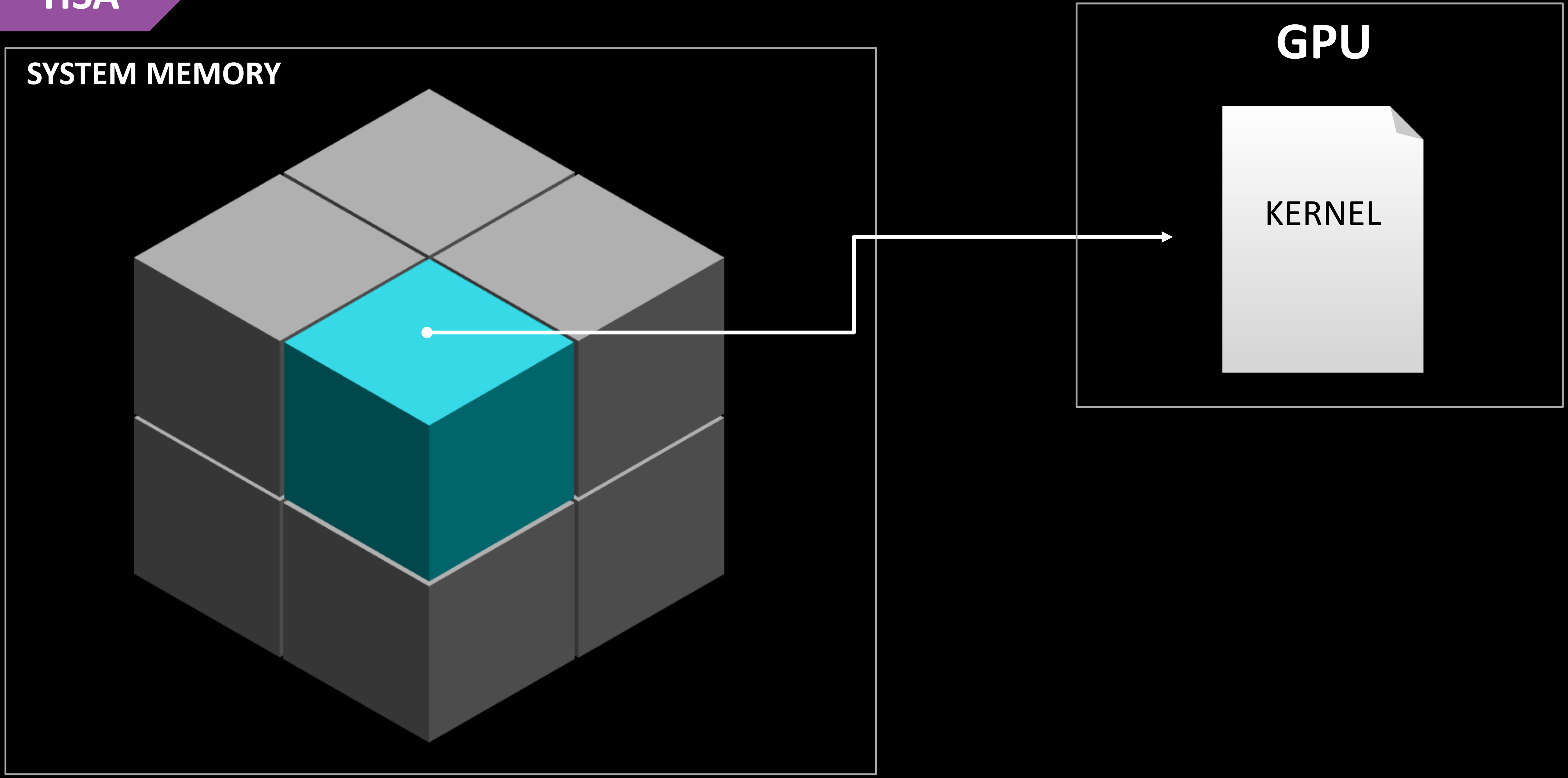
Level 1 Level 2 Level 3 Level 4 Level 5

HSA



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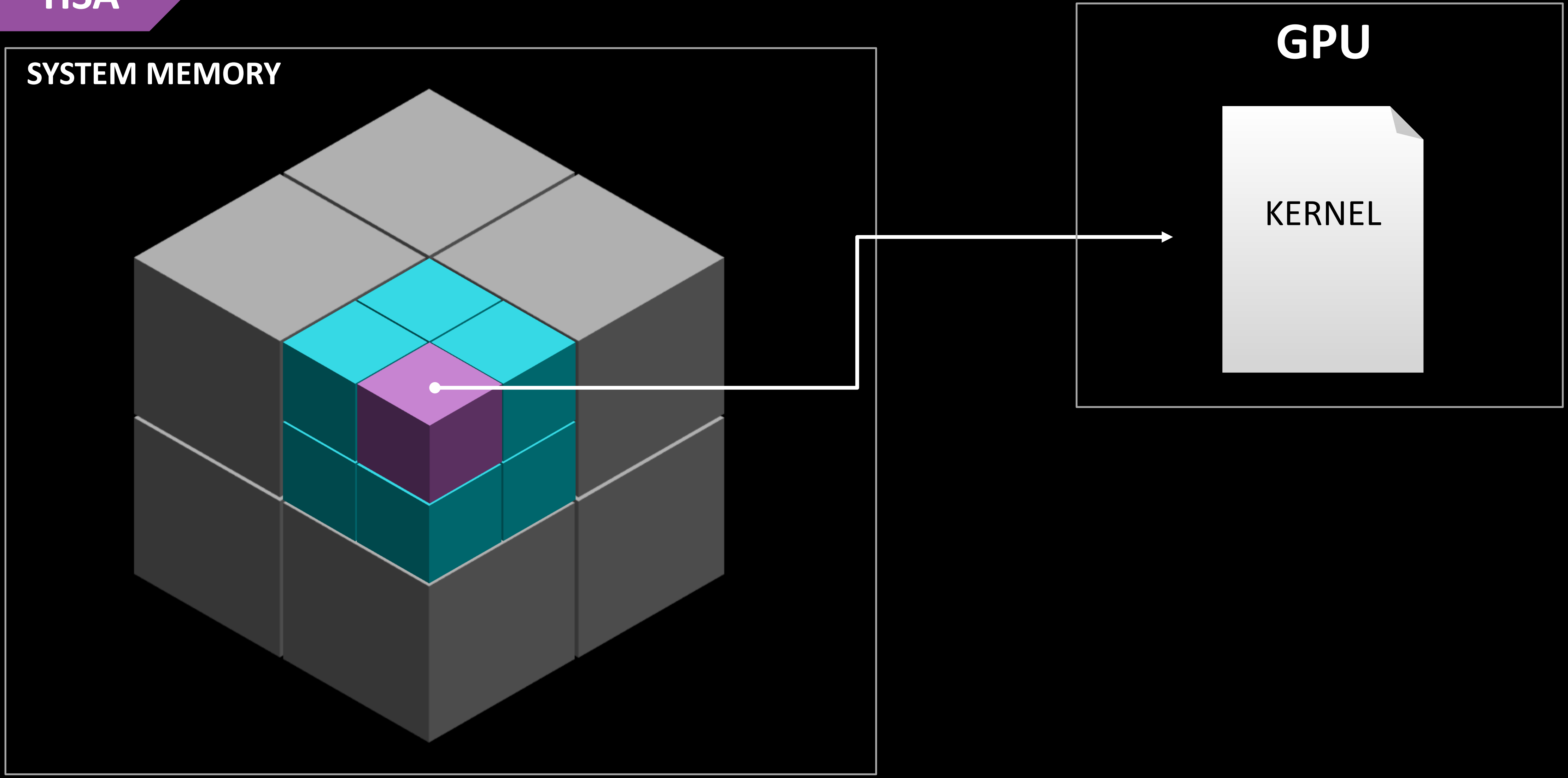
HSA



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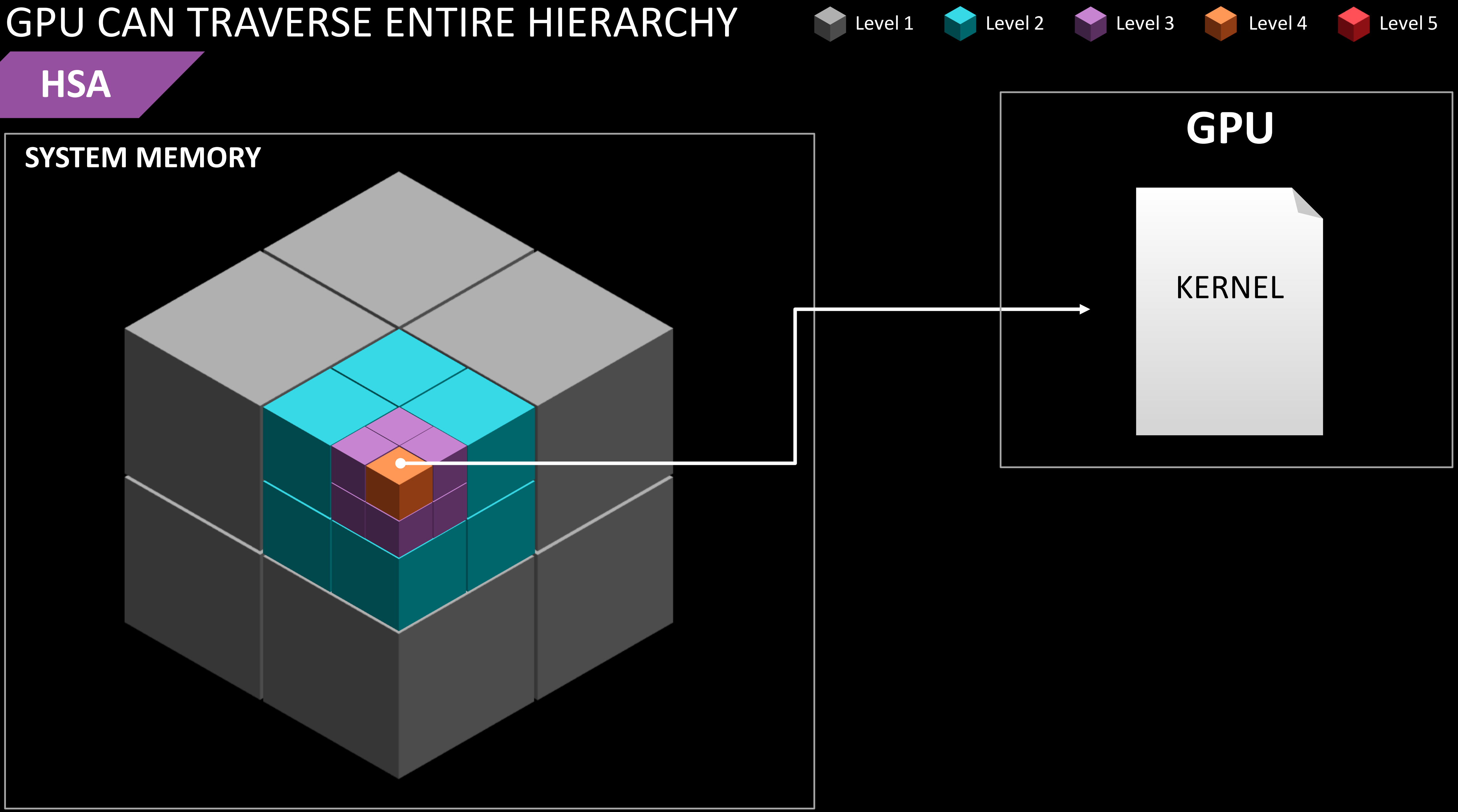
HSA

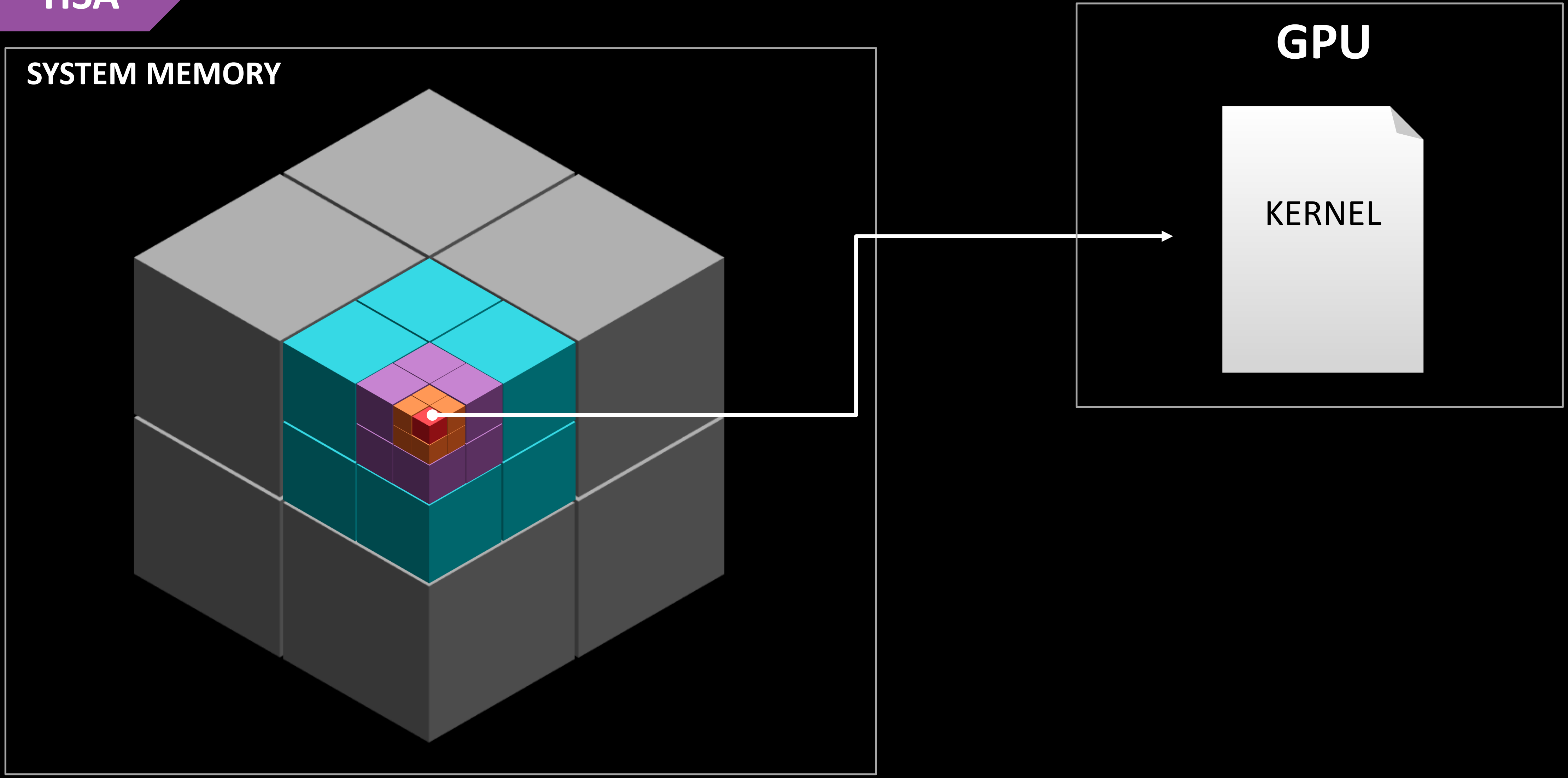


# GPU CAN TRAVERSE ENTIRE HIERARCHY

Level 1 Level 2 Level 3 Level 4 Level 5

AMD

**HSA**



# LEGACY ACCESS USING GPU MEMORY

Legacy

**SYSTEM MEMORY**

**GPU**

**GPU MEMORY**

GPU Memory is smaller

Have to copy and process in chunks

# LEGACY ACCESS TO LARGE STRUCTURES

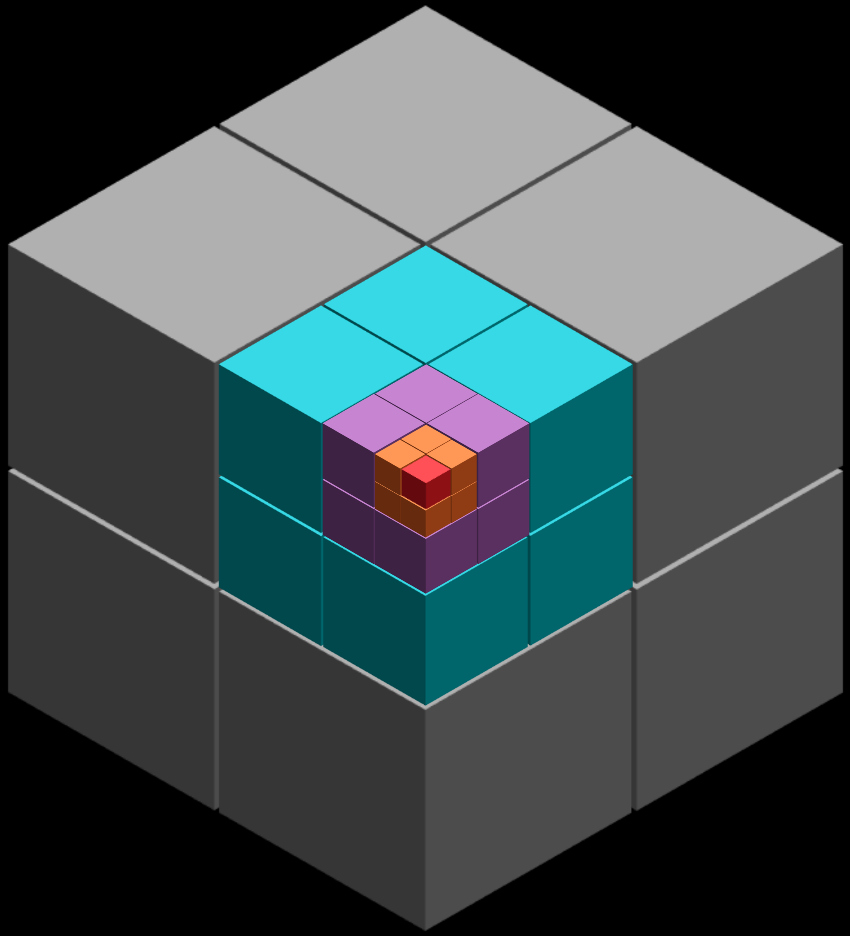
Level 1 Level 2 Level 3 Level 4 Level 5

AMD

Legacy

**SYSTEM MEMORY**

Large 3D spatial data structure



**GPU**

**GPU MEMORY**

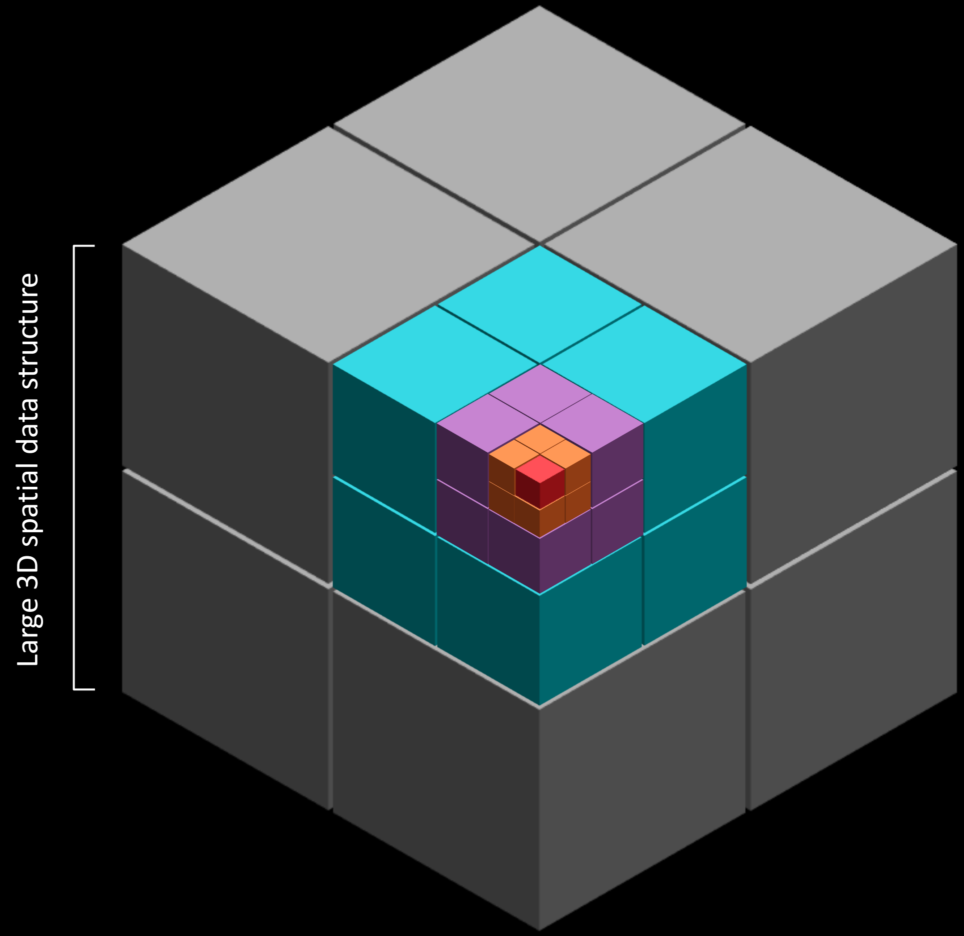
# COPY ONE CHUNK AT A TIME

Level 1 Level 2 Level 3 Level 4 Level 5

AMD

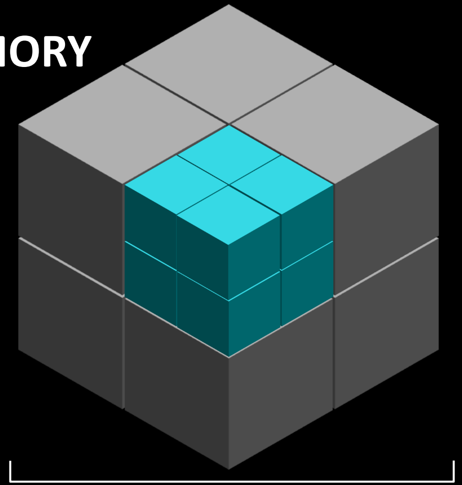
Legacy

## SYSTEM MEMORY




## GPU

## GPU MEMORY

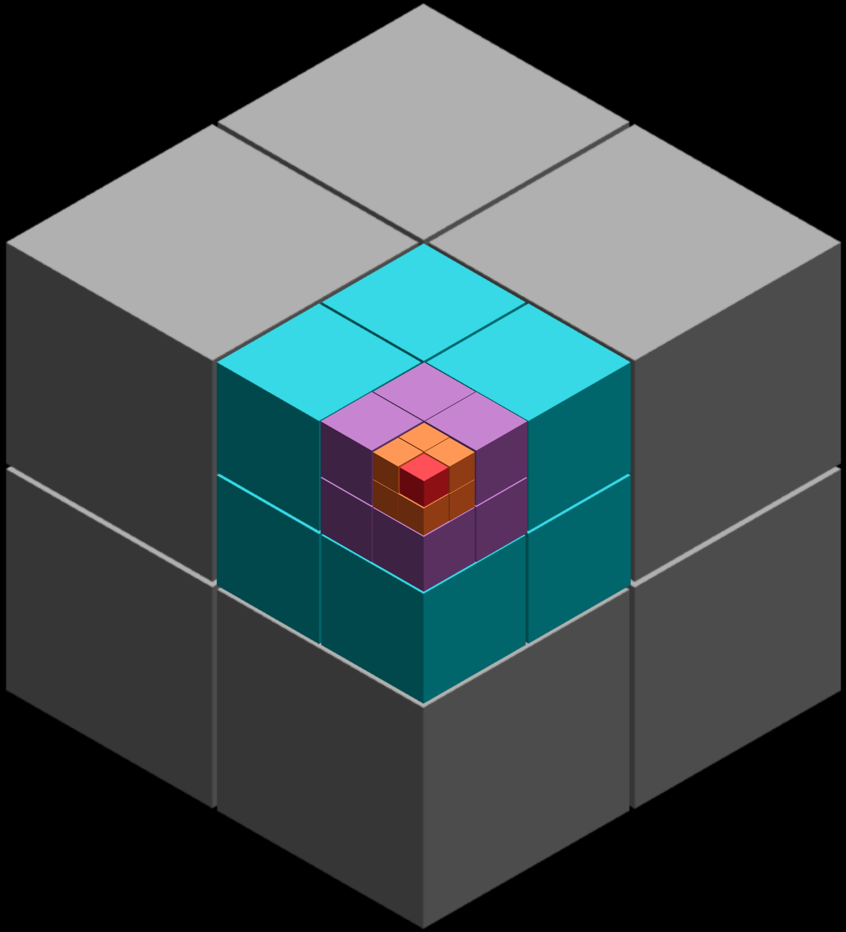


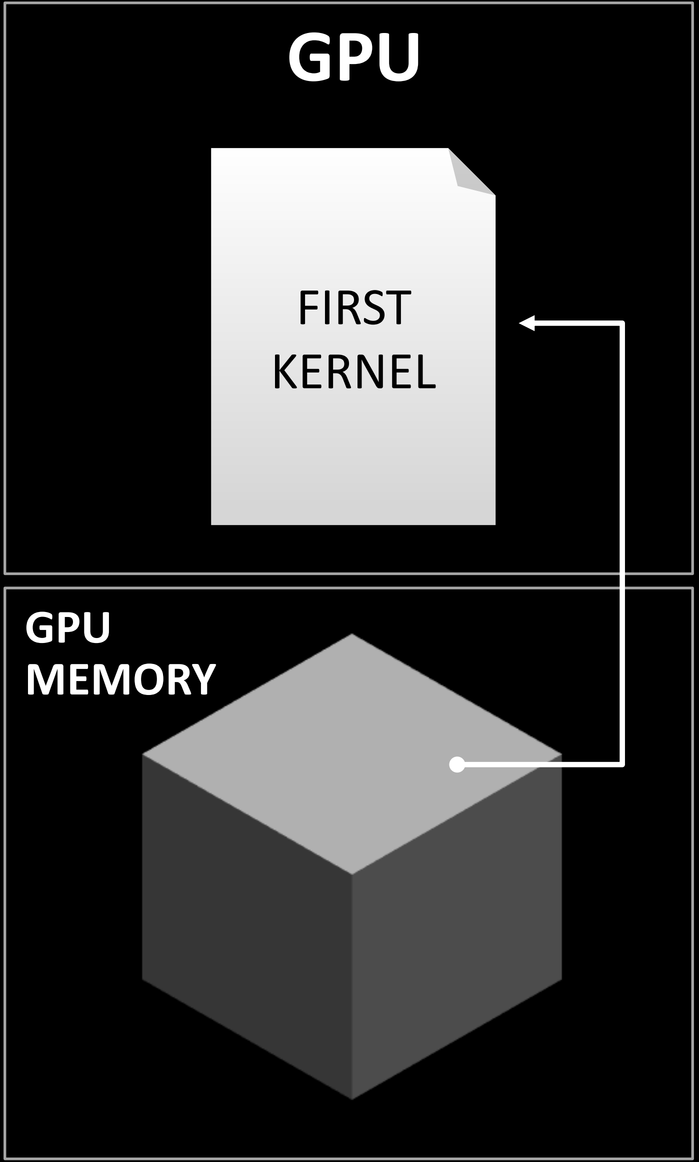
# PROCESS ONE CHUNK AT A TIME

Level 1 Level 2 Level 3 Level 4 Level 5

Legacy

**SYSTEM MEMORY**

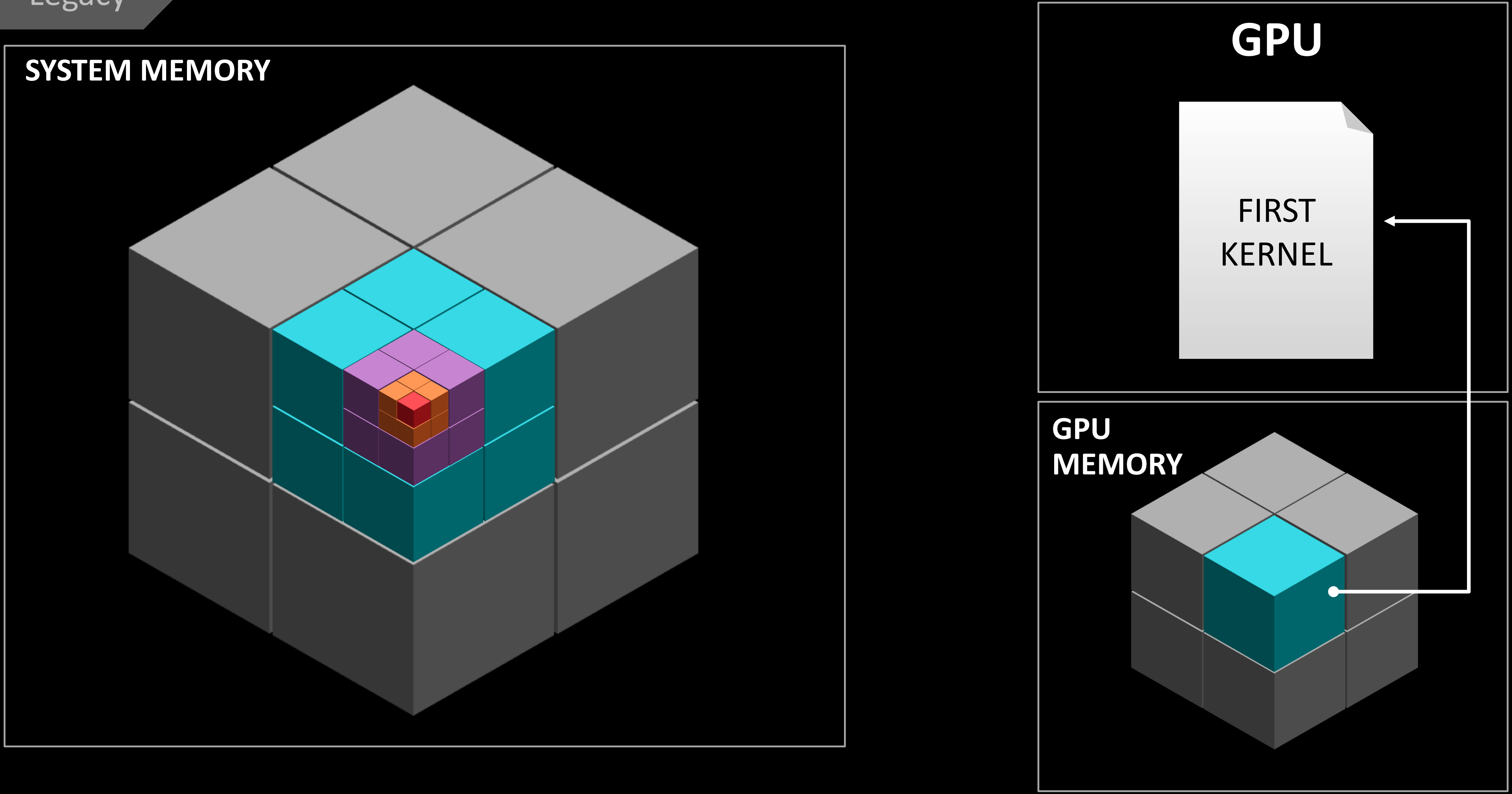




# PROCESS ONE CHUNK AT A TIME

Level 1 Level 2 Level 3 Level 4 Level 5

Legacy



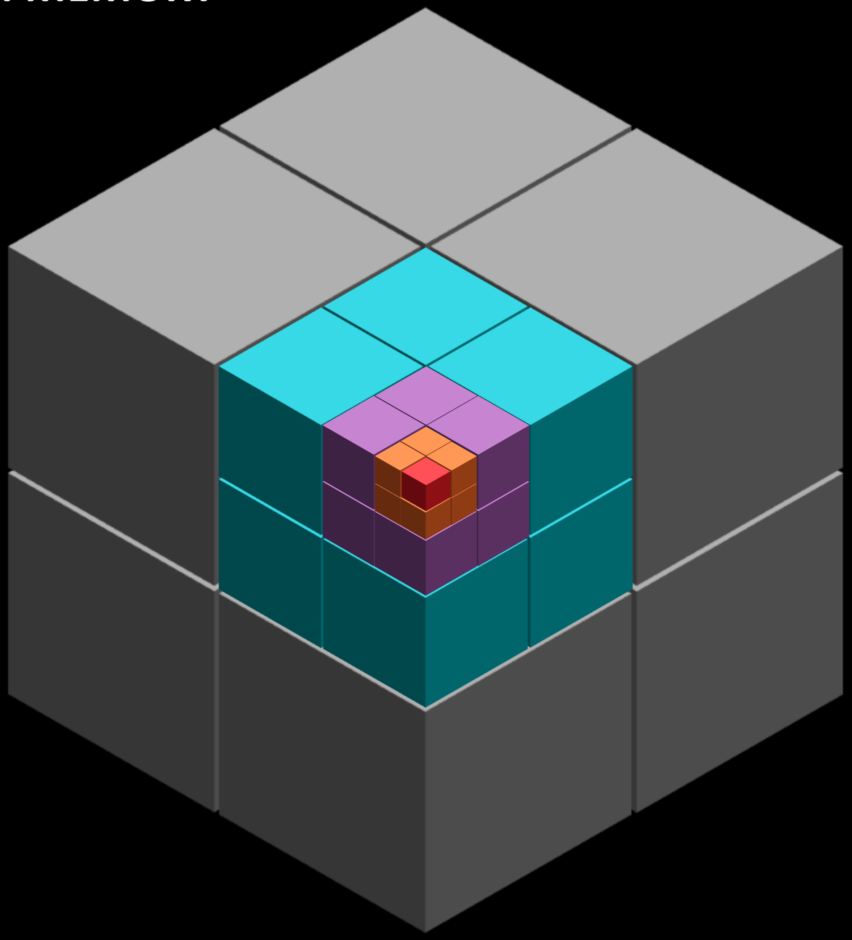
# PROCESS ONE CHUNK AT A TIME

Level 1 Level 2 Level 3 Level 4 Level 5

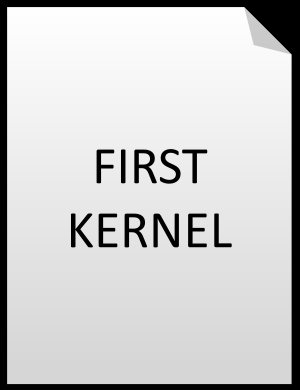
AMD

Legacy

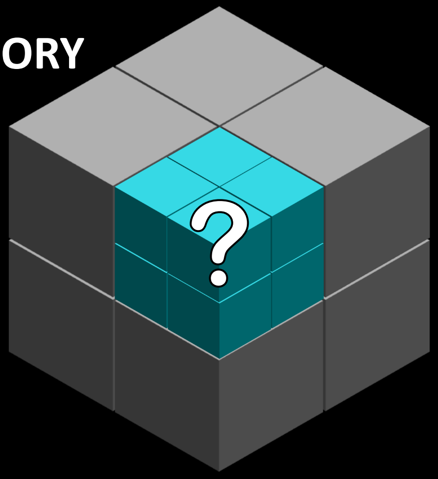
**SYSTEM MEMORY**



**GPU**




**GPU MEMORY**



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Level 1 Level 2 Level 3 Level 4 Level 5

AMD

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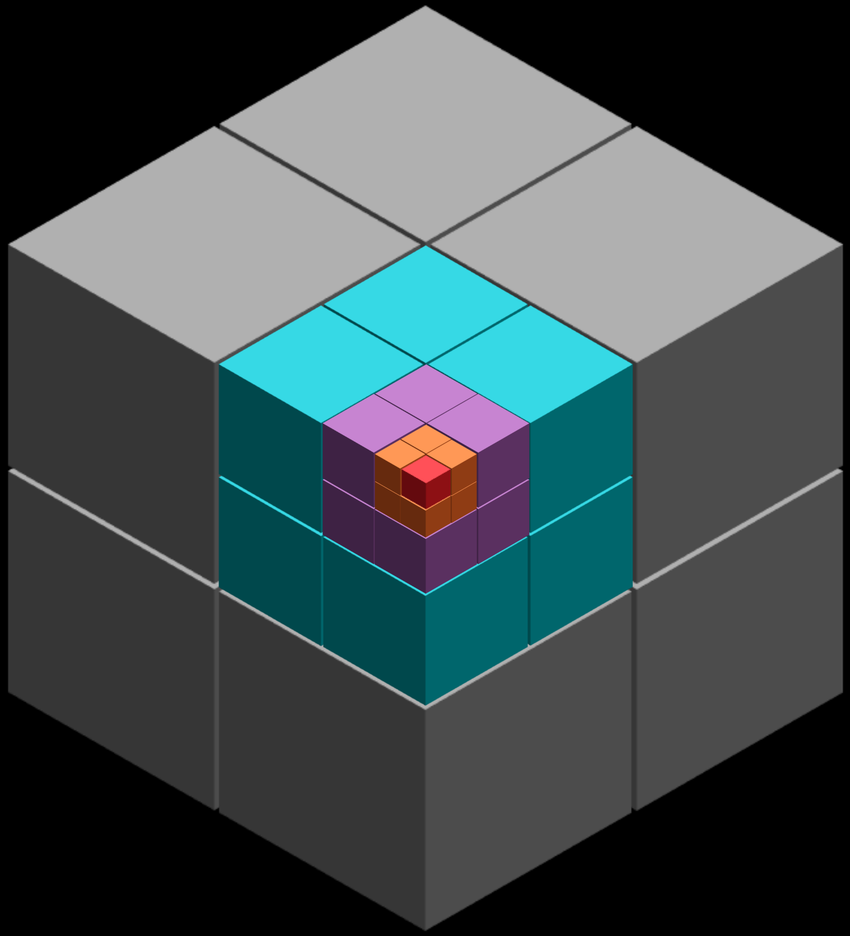
**SYSTEM MEMORY**

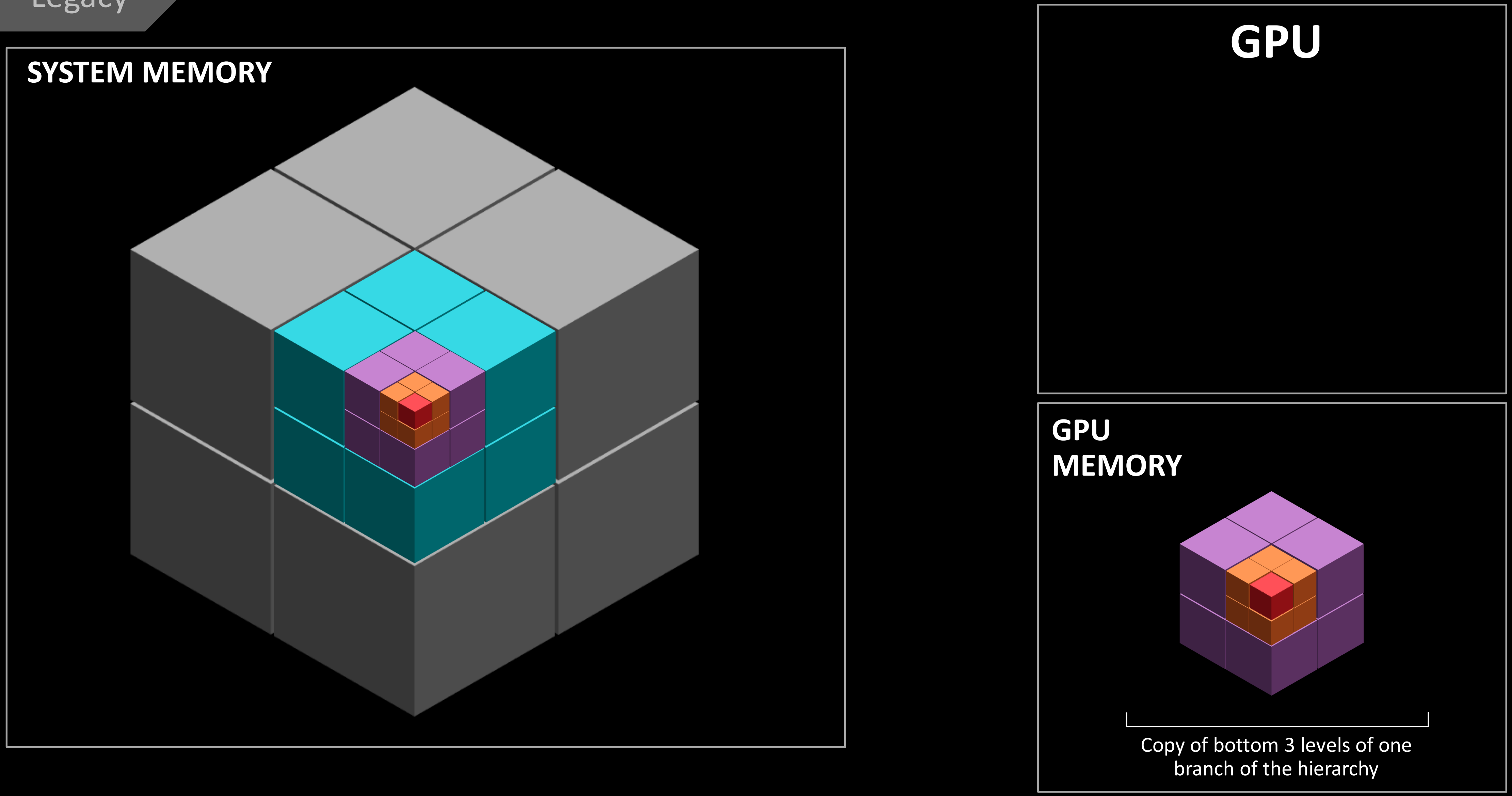


**GPU**

**GPU MEMORY**

# COPY ONE CHUNK AT A TIME


Legacy

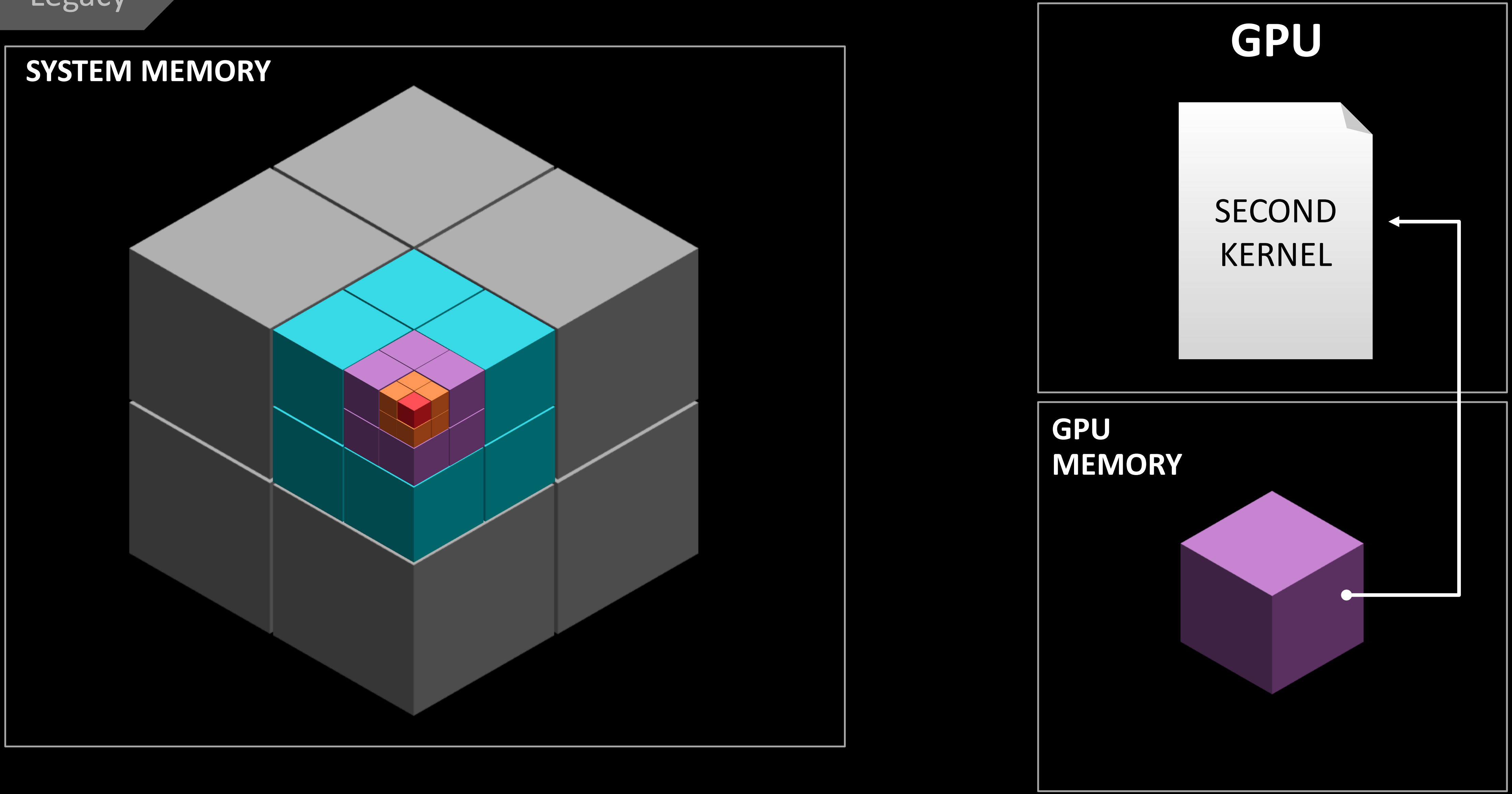


# PROCESS ONE CHUNK AT A TIME

Level 1 Level 2 Level 3 Level 4 Level 5

AMD

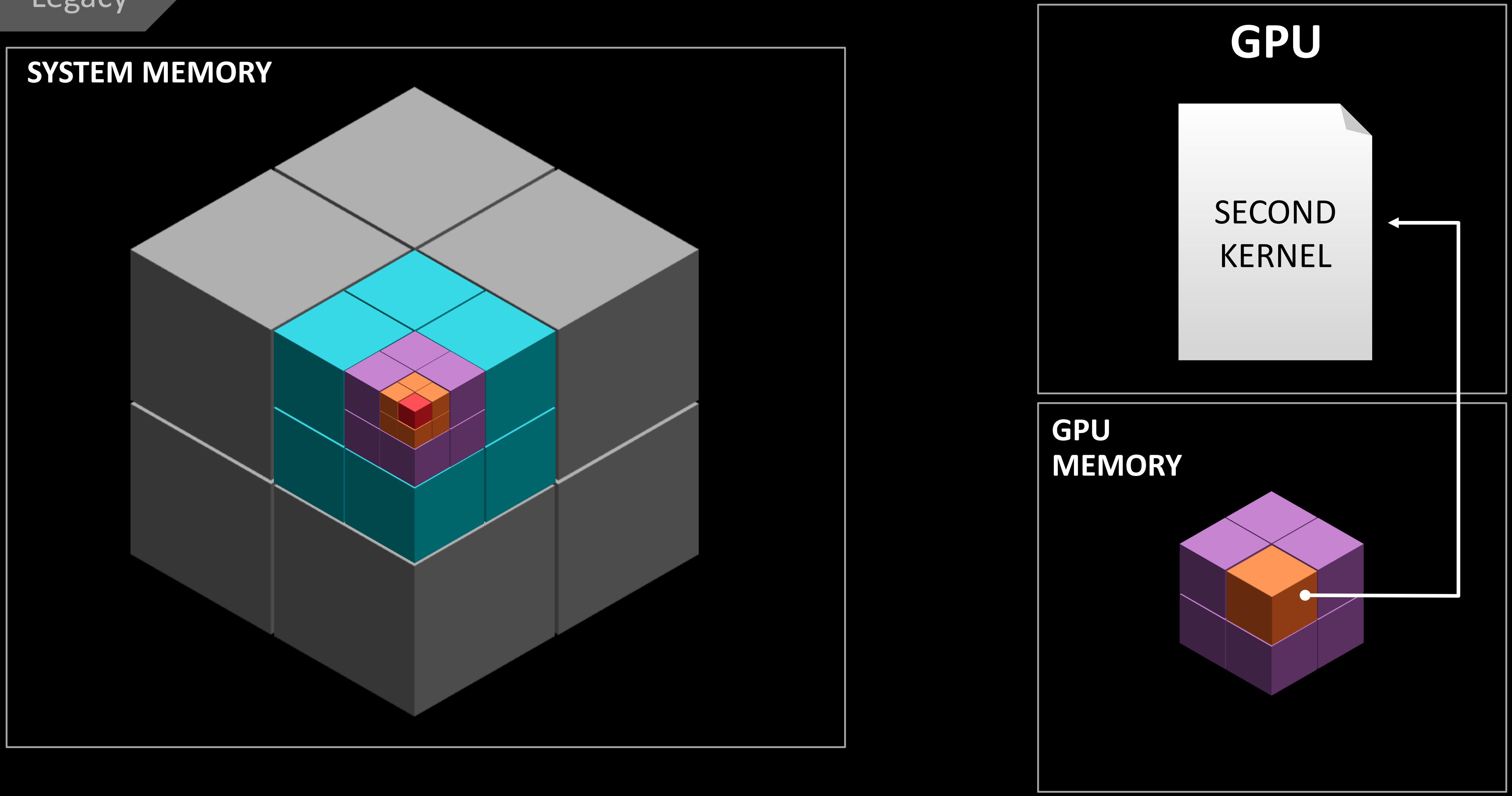
Legacy



# PROCESS ONE CHUNK AT A TIME

Level 1 Level 2 Level 3 Level 4 Level 5

Legacy

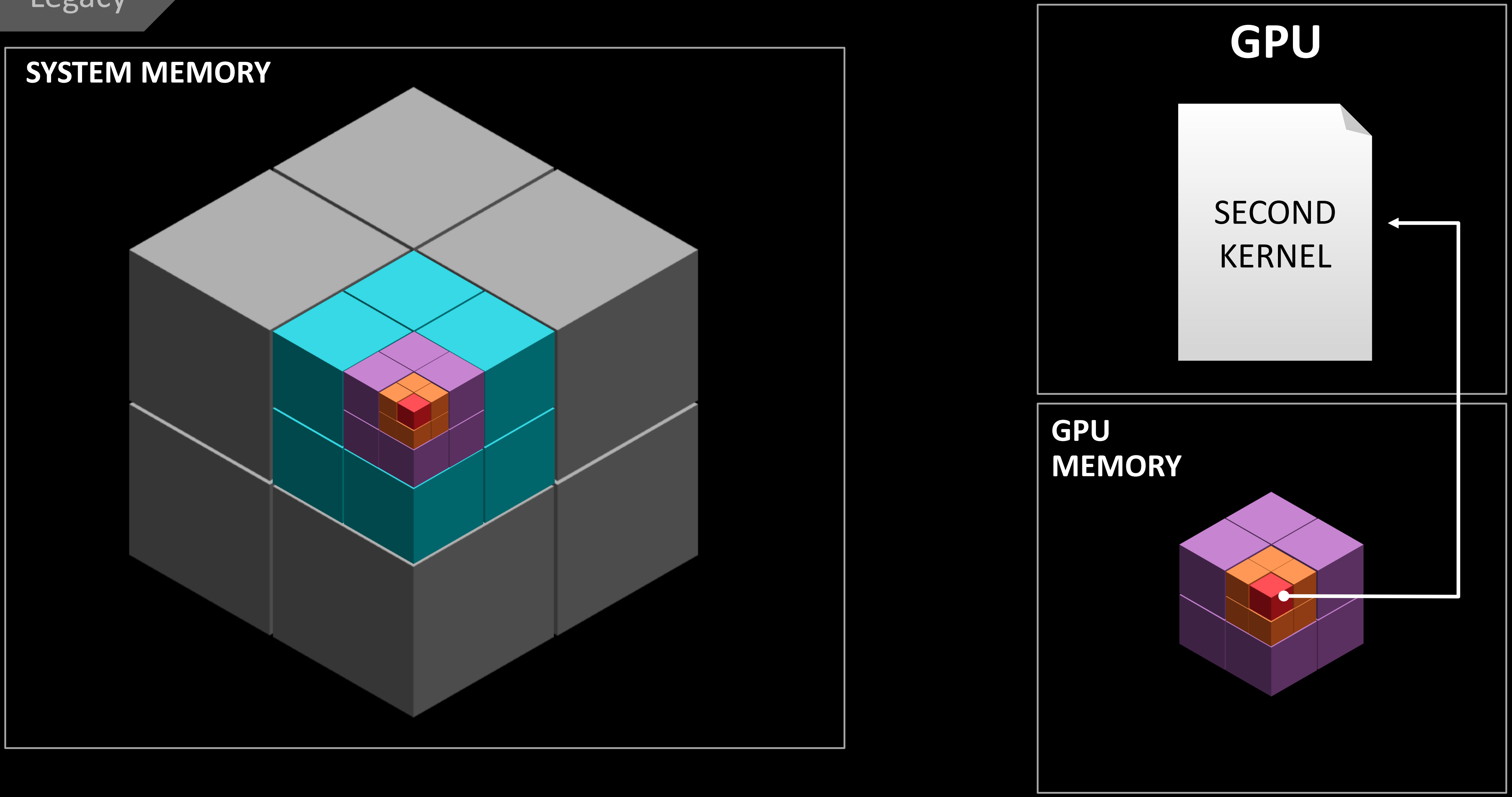


# PROCESS ONE CHUNK AT A TIME

Level 1 Level 2 Level 3 Level 4 Level 5

AMD

Legacy



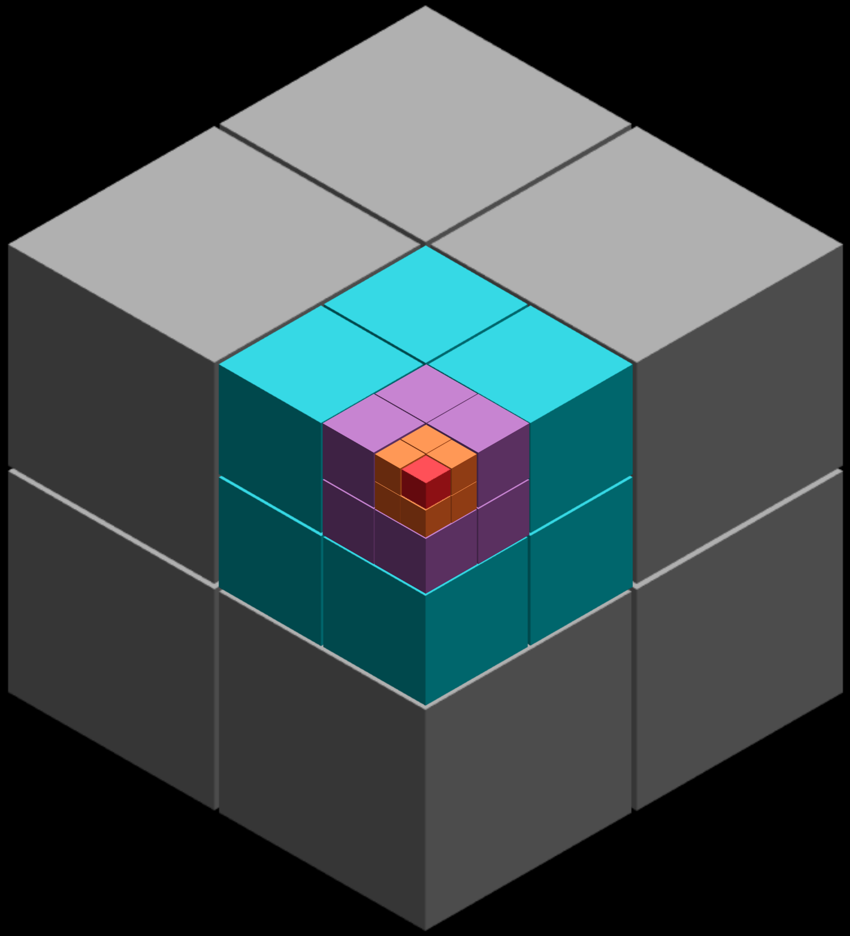
# COPY ONE CHUNK AT A TIME

Level 1 | Level 2 | Level 3 | Level 4 | Level 5

AMD

Legacy

**SYSTEM MEMORY**

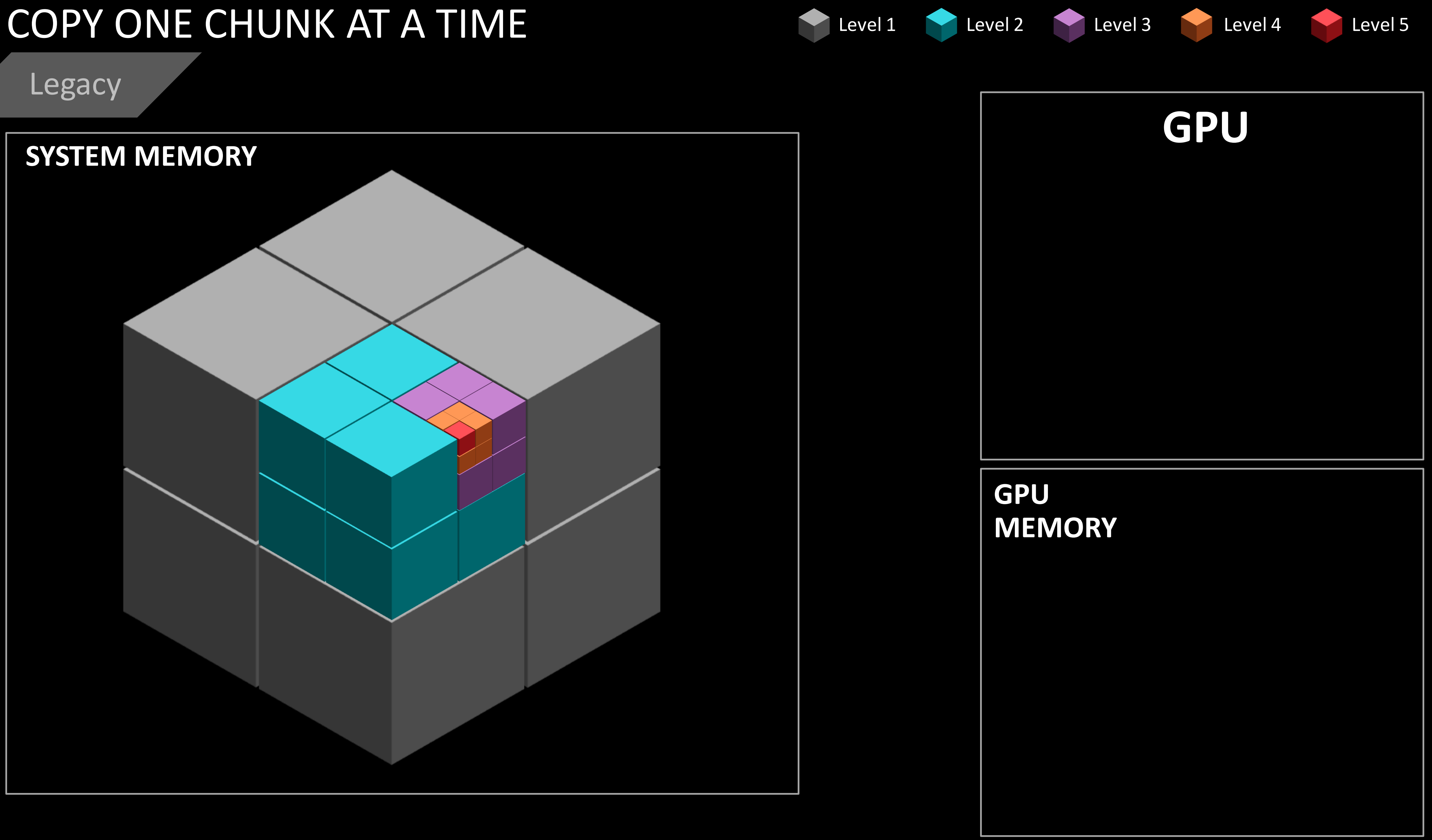


**GPU**

**GPU MEMORY**

# COPY ONE CHUNK AT A TIME

Legacy

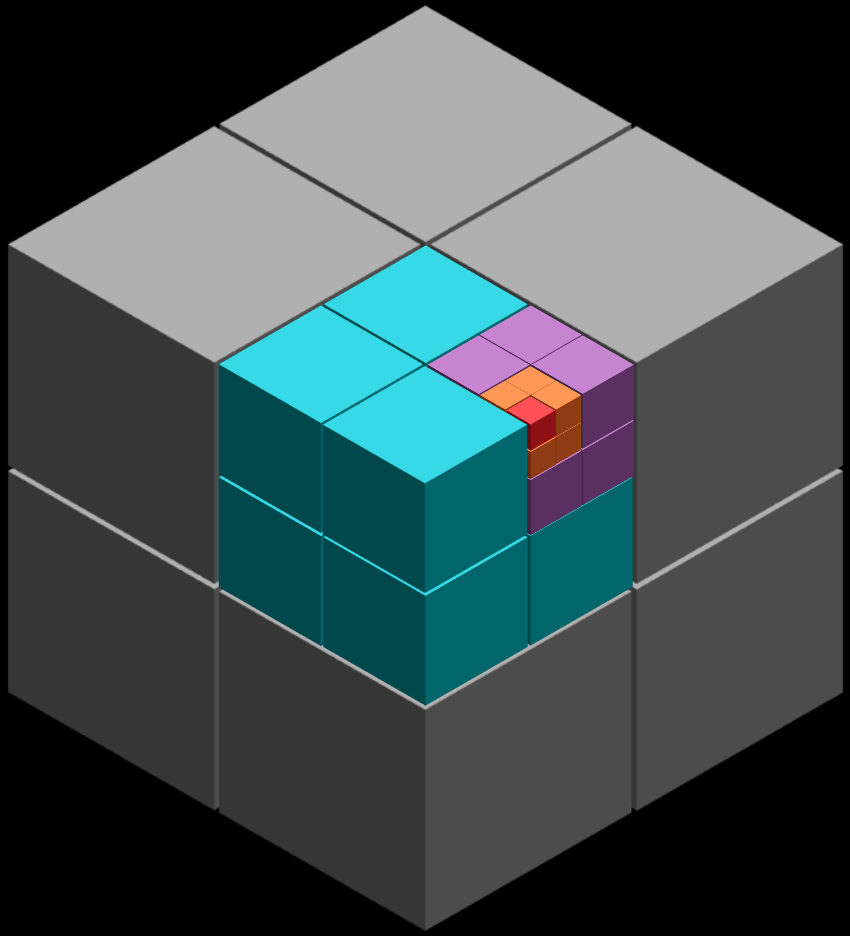


# COPY ONE CHUNK AT A TIME

Level 1 Level 2 Level 3 Level 4 Level 5

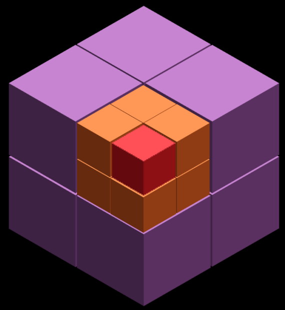
Legacy

SYSTEM MEMORY



GPU

GPU MEMORY



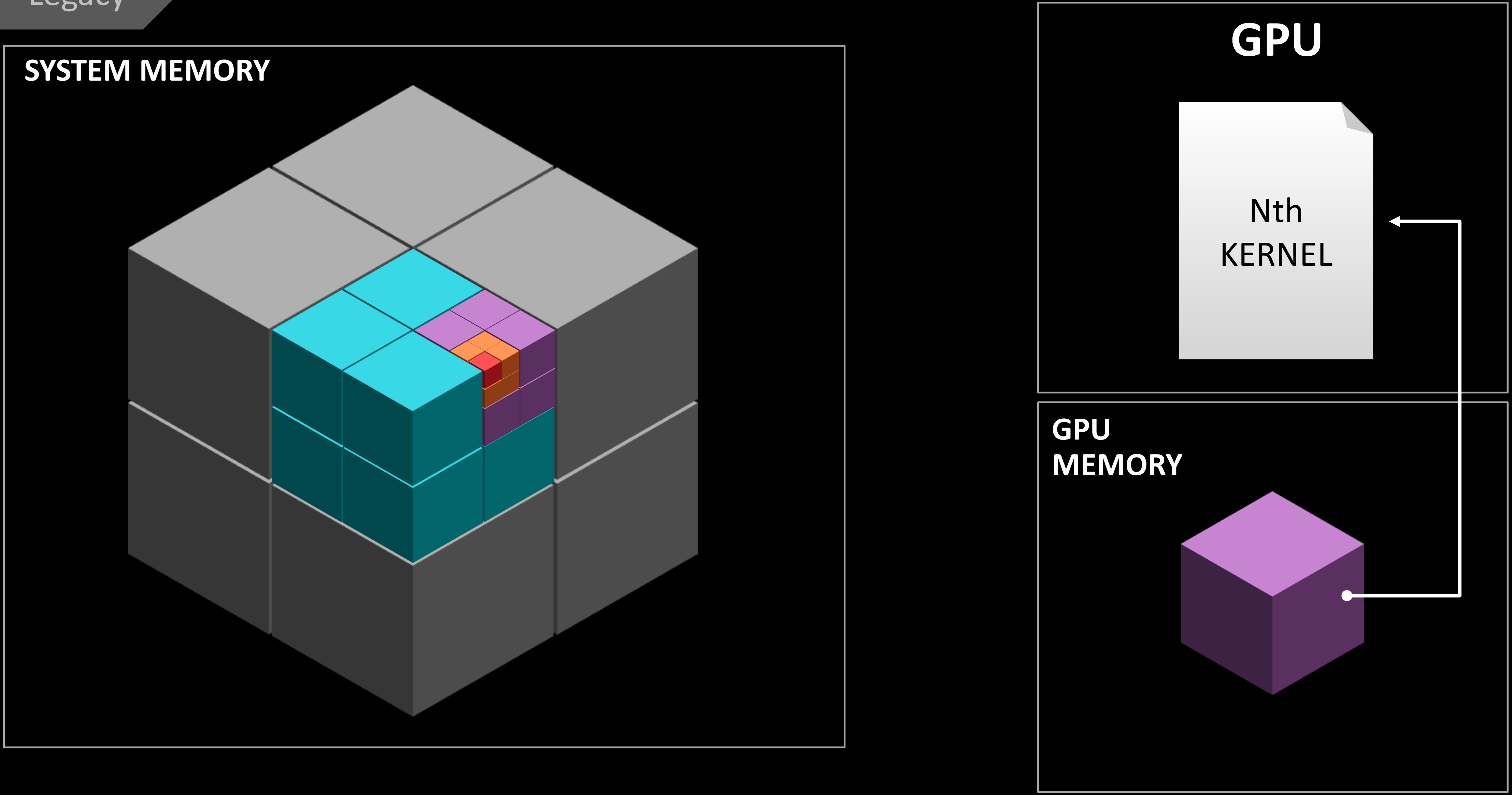
Copy of bottom 3 levels of a different branch of the hierarchy

# PROCESS ONE CHUNK AT A TIME

Level 1 Level 2 Level 3 Level 4 Level 5

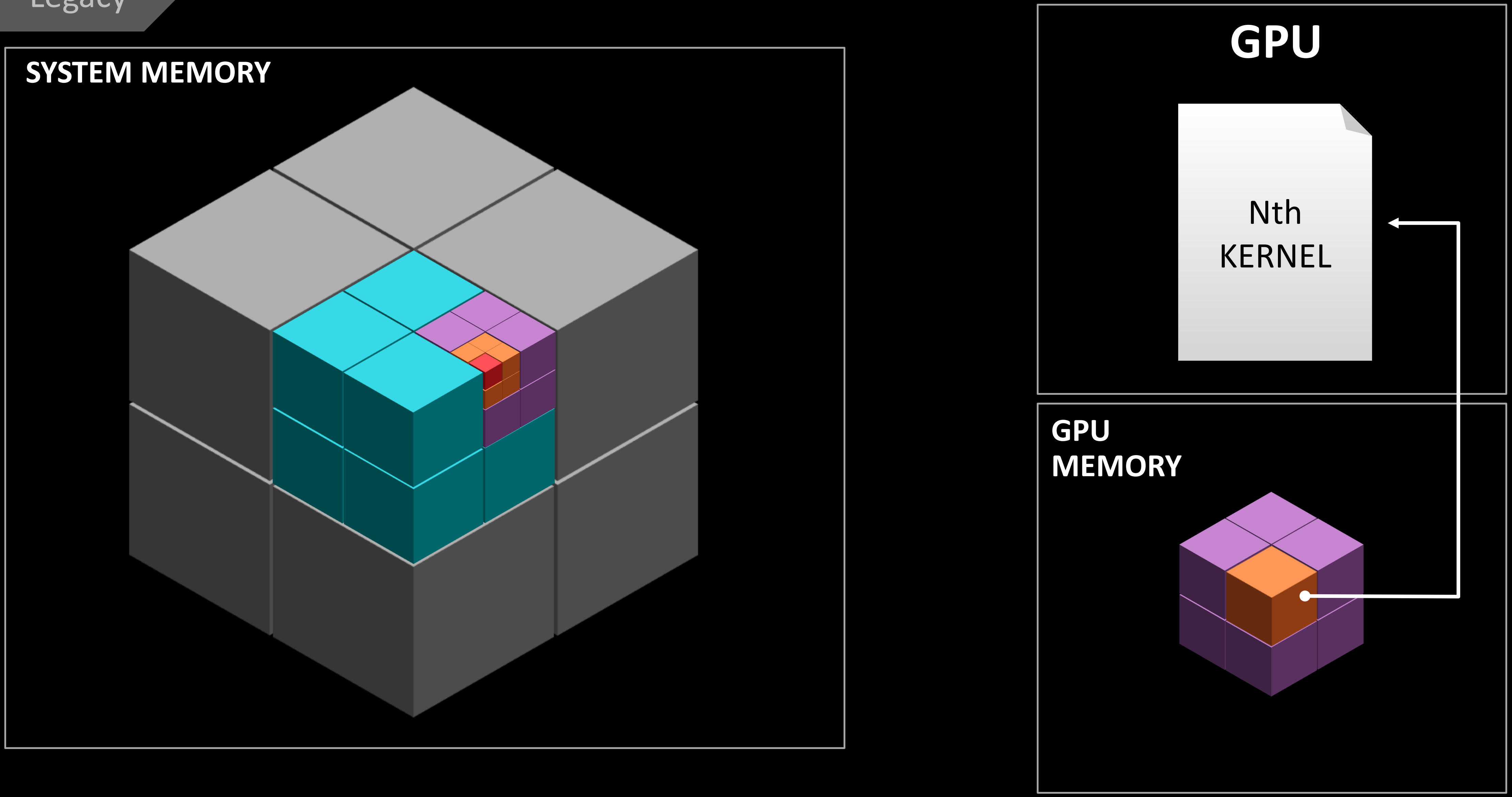
AMD

Legacy



# PROCESS ONE CHUNK AT A TIME


Legacy

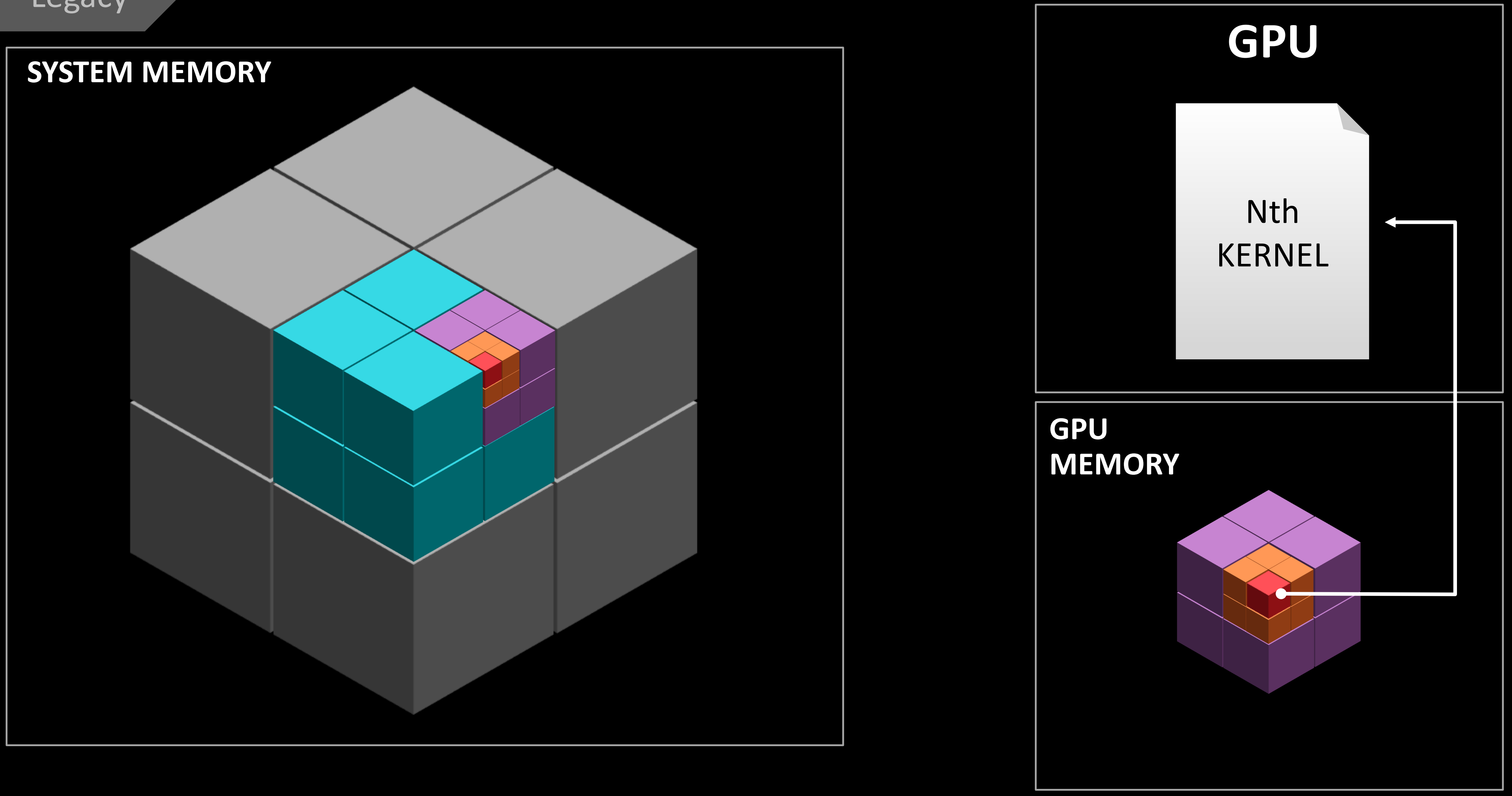


# PROCESS ONE CHUNK AT A TIME

Level 1 Level 2 Level 3 Level 4 Level 5

AMD

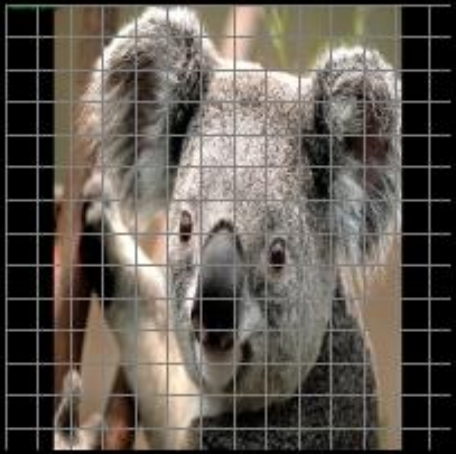
Legacy



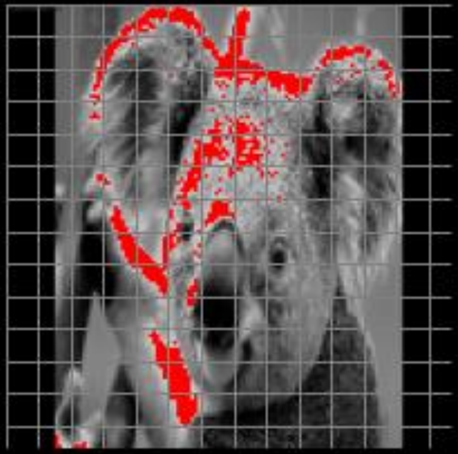
# Callbacks

# CALLBACKS
## COMMON SITUATION IN HC

- Parallel processing algorithm with branches
- A seldom taken branch requires new data from the CPU
- On legacy systems, the algorithm must be split:
  - Process Kernel 1 on GPU
  - Check for CPU callbacks and if any, process on CPU
  - Process Kernel 2 on GPU



Input Image

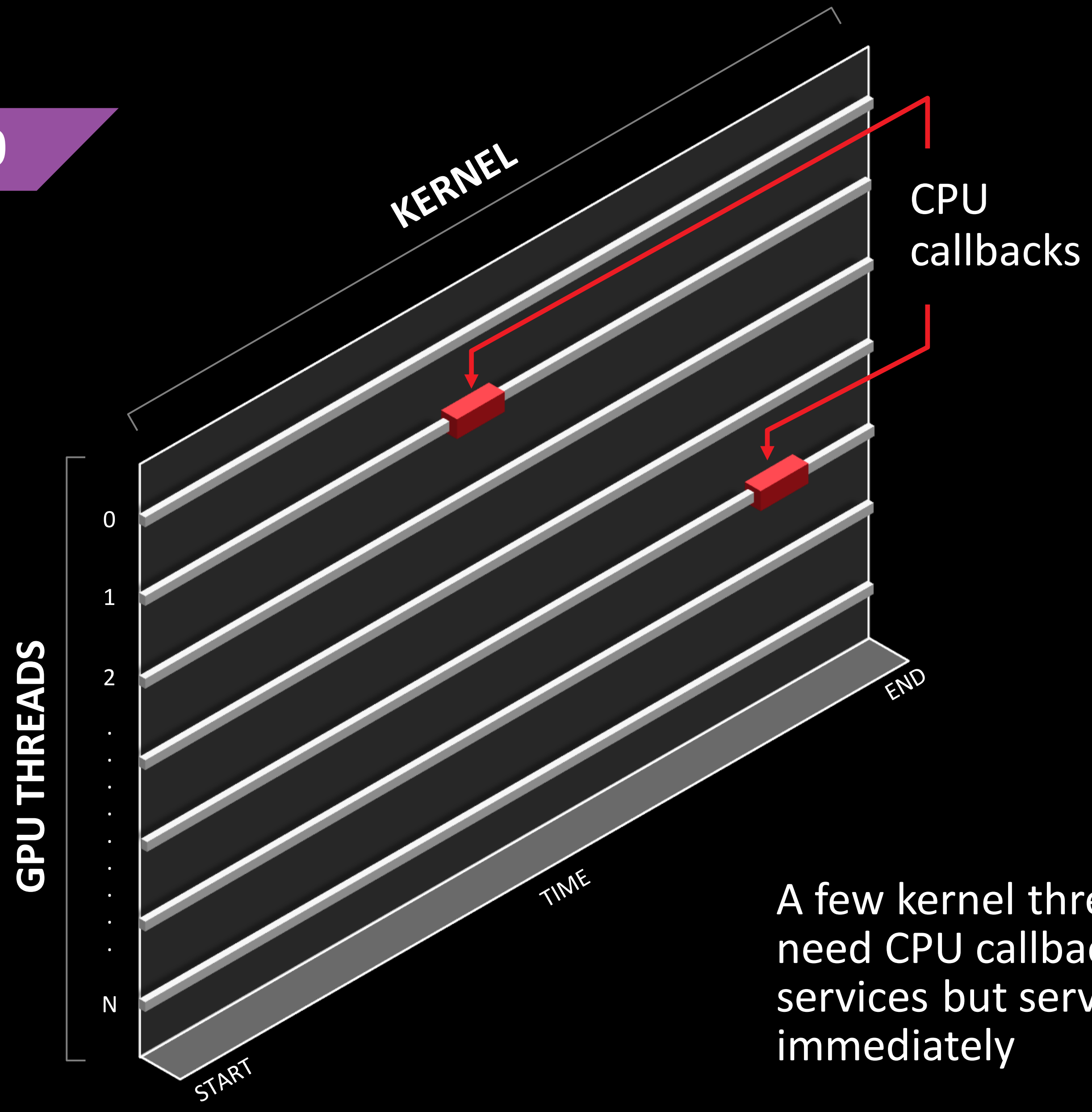


Output Image

- Example algorithm from Image Processing
  - Perform a filter
  - Calculate average LUMA in each tile
  - Compare LUMA against threshold and call CPU callback if exceeded (rare)
  - Perform special processing on tiles with callbackx\s

# CALLBACKS

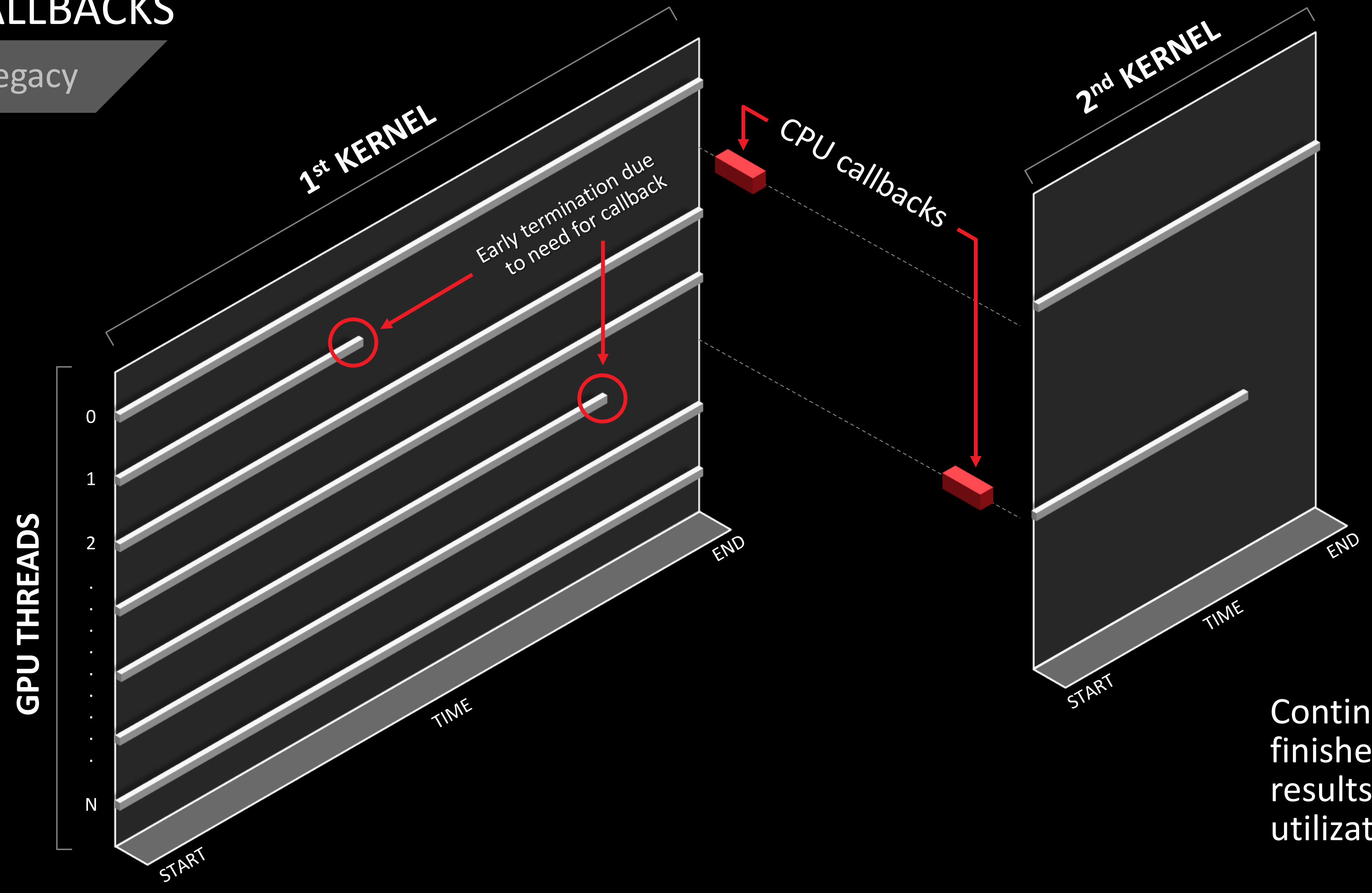
## HSA and full OpenCL 2.0




A few kernel threads need CPU callback services but serviced immediately

# CALLBACKS

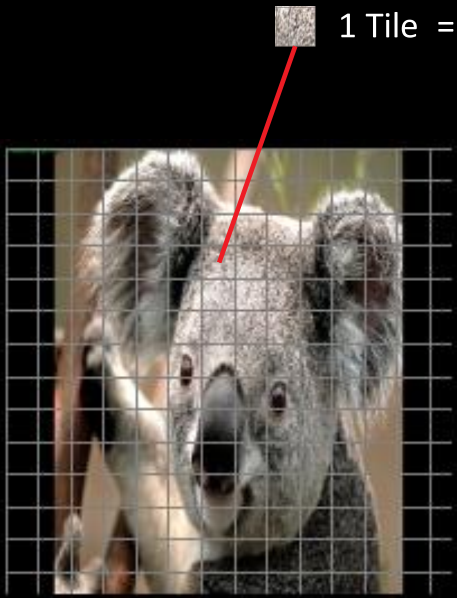
Legacy



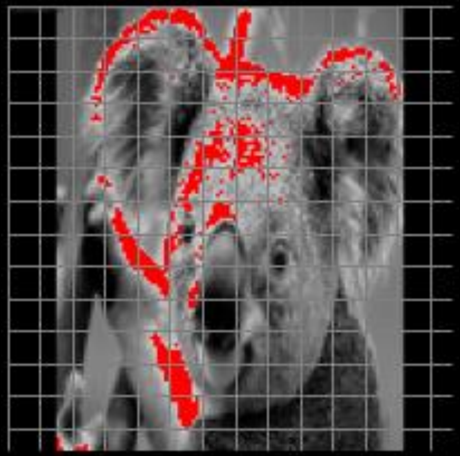

Continuation kernel finishes up kernel works results in poor GPU utilization

**GPU to CPU callbacks use Shared Virtual Memory (SVM) Semaphores, implemented using Platform Atomic Compare-and-Swap.**

1 Tile = 1 OpenCL Work Item



Input Image



Output Image

## GPU

- Work items compute average RGB value of all the pixels in a tile
- Work items also compute average Luma from the average RGB
- If average Luma > threshold, workgroup invokes CPU CALLBACK
- In parallel with callback, compute data used to saturate LUMA

## CPU

- For selected tiles, update average Luma value (set to RED)

## GPU

- Work items apply the Luma value to all pixels in the tile

# AMD HETEROGENEOUS COMPUTING SOLUTIONS OVERVIEW

DEVELOPER TOOLS

PROGRAMMING LANGUAGES

OPTIMIZED LIBRARIES

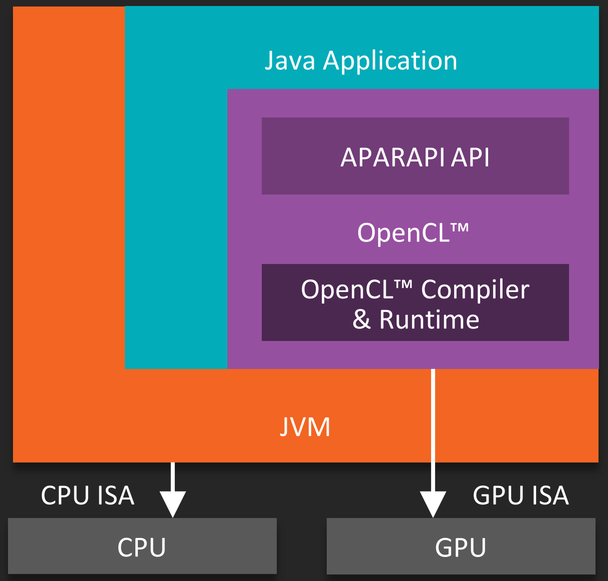
***Unified SDKs***

***Web Resources and Developer Forums***

# HSA ENABLEMENT OF JAVA

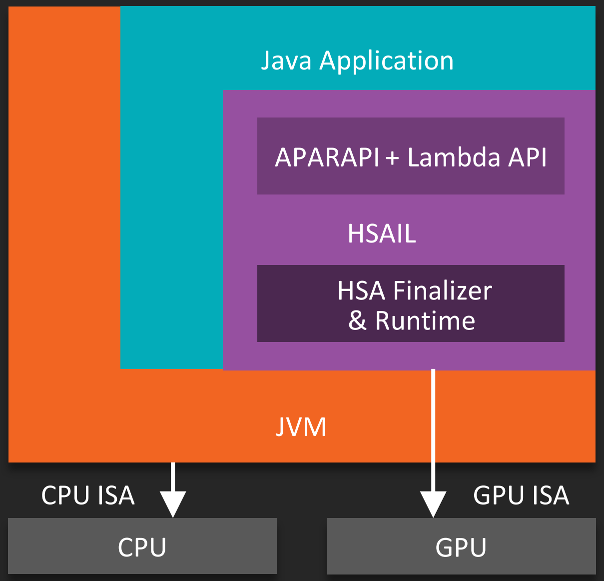
## JAVA 7 – OpenCL™ ENABLED APARAPI

- AMD initiated Open Source project
- Program only in Java
  - Accelerated by OpenCL™
- Active community captured mindshare



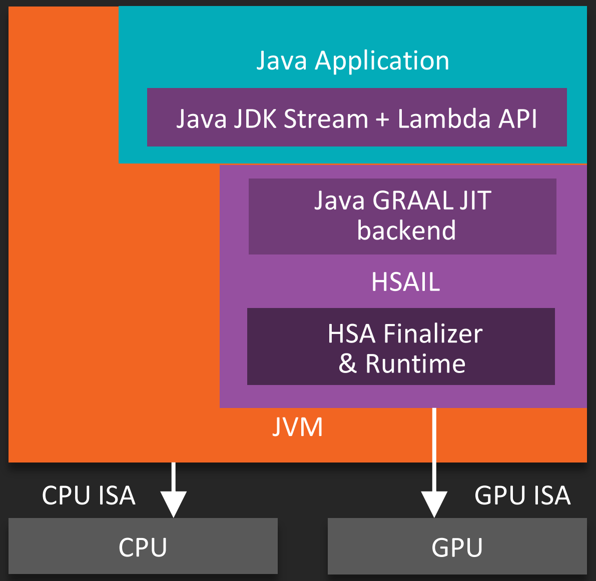

## JAVA 8 – HSA ENABLED APARAPI

- Java 8 adds Stream, Lambda APIs
  - CPU Multicore Parallelism
- APARAPI on HSA accelerates Lambdas
  - Parallel acceleration on HSA APU




## JAVA 9 – HSA ENABLED JAVA (SUMATRA)

- Adds native APU acceleration to Java Virtual Machine (JVM)
- Developer uses Lambda, Stream API
- JVM generates HSAIL automatically



# AMD'S UNIFIED SDK

AMD

- Access to AMD APU and GPU programmable components
- Component installer - choose just what you need
- Initial release includes:
- APP SDK v2.9
- Media SDK 1.0

**AMD Unified SDK**

## APP SDK 2.9

- Web-based sample browser
- Supports programming standards:  OpenCL™, C++ AMP
- Code samples for accelerated open source libraries:
  - OpenCV, OpenNI, Bolt, Aparapi
- OpenCL™ source editing plug-in for visual studio
- Now supports Cmake

## MEDIA SDK 1.0

- GPU accelerated video pre/post processing library
- Leverage AMD's media encode/decode acceleration blocks
- Library for low latency video encoding
- Supports both Windows Store and Classic desktop

# AMD CODE XL V1.3

AMD

- AMD's comprehensive heterogeneous developer tool suite including:
  - CPU and GPU Profiling
  - GPU kernel Debugging
  - GPU kernel analysis

- New features in version 1.3:
  - Supports Java, the world's most popular programming language
  - Integrated static kernel analysis
  - Remote debugging/profiling
  - Supports latest AMD APU and GPU products

## CPU PROFILER

- Time-based profiling
- Analyze call-chain relationships
- Java profiling with inline function support
- Cache-line utilization profiling
- Supports latest AMD processors

## GPU PROFILER

- OpenCL Application Trace
- Profile OpenCL kernels
- Timeline visualization of GPU counter data
- Kernel Occupancy Viewer
- Remote GPU Profiling

## GPU DEBUGGER

- Real-time OpenCL kernel debugging with stepping and variable display
- OpenCL and OpenGL API Statistics
- Object visualization
- Remote GPU debugging

## STATIC KERNEL ANALYZER

- Compile, analyze and disassemble OpenCL Kernels
- View kernel compilation errors/warnings
- Estimate kernel performance
- View generated ISA code
- View registers

# ACCELERATED OPEN SOURCE LIBRARIES

AMD

## OpenCV

- Most popular computer vision library
- Now with many OpenCL™ accelerated functions

## Bolt

- C++ template library
- Provides GPU off-load for common data-parallel algorithms
- Now with cross-OS support and improved performance/functionality

## clMath

- AMD released APPML as open source to create clMath
- Accelerated BLAS and FFT libraries
- Accessible from Fortran, C and C++

## Aparapi

- OpenCL accelerated Java 7
- Java APIs for data parallel algorithms (no need to learn OpenCL)

# "KAVERI" AND HSA HAVE ARRIVED

## THE REVOLUTION HAS STARTED!

# Questions?

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**ATTRIBUTION**

# Backup

# MICRO-BENCHMARK SYSTEM CONFIGURATION

AMD

| Details | AMD “Kaveri” APU |
| --- | --- |
| Operating System | Microsoft® Windows 8.1® (64-bit)<br>Single Language |
| Processor | "Kaveri" A10 – 95W<br>AMD Engineering Sample<br>ZD376091I4468_40/37/18/07_130F |
| CPU speed (base/boost) | 3.7 GHz / 4.0 GHz |
| GPU speed | 720 MHz |
| Memory | 2x4GB DDR3-1600 |
| Disk | HDD |
| Video Driver | 13.35 / HSA Beta 2.2 |
| Test Dates | January 1-3, 2014 |