Avoiding Catastrophic Performance Loss

Detecting CPU-GPU Sync Points

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Topics

- D3D/GL Driver Models
- Types of Sync Points
- How bad are they, really?
- Detection
- Repair
- Summary

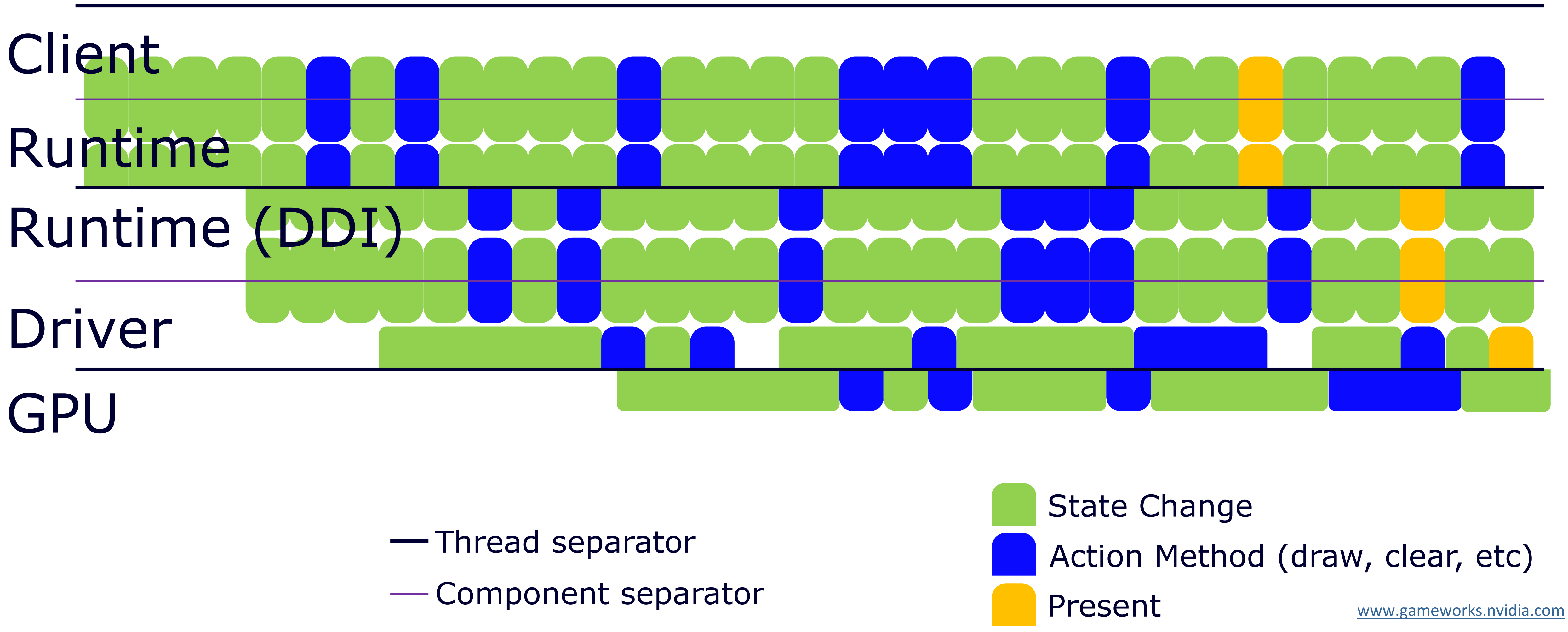
D3D Driver Model

- Multithreaded
  - Client Thread (Your Application + D3D Runtime)
  - Server Thread (D3D Runtime [DDI] + Driver)
  - GPU (??)
- Remains in user-mode for as long as possible

GL Driver

- Very similar
  - Client thread (your application + GL entry points)
  - Server thread (shelved data + expansion)
  - GPU
- Again, very little time in Kernel Mode

Example Healthy Timeline



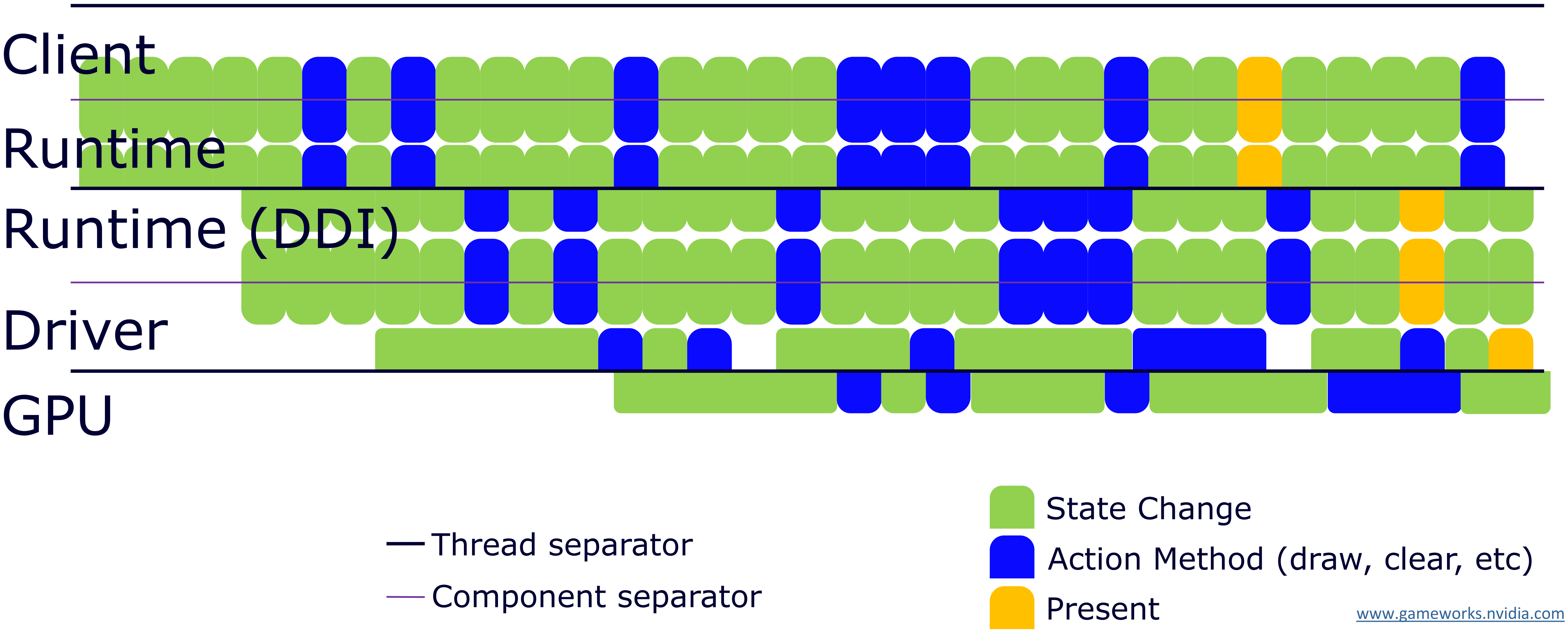
Types of Sync Points

- Driver Sync Point ☹ ☹
- CPU-GPU Sync Point
  - Can be Server->GPU ☹ ☹ ☹
  - Can be Client->GPU ☹ ☹ ☹ ☹ ☹

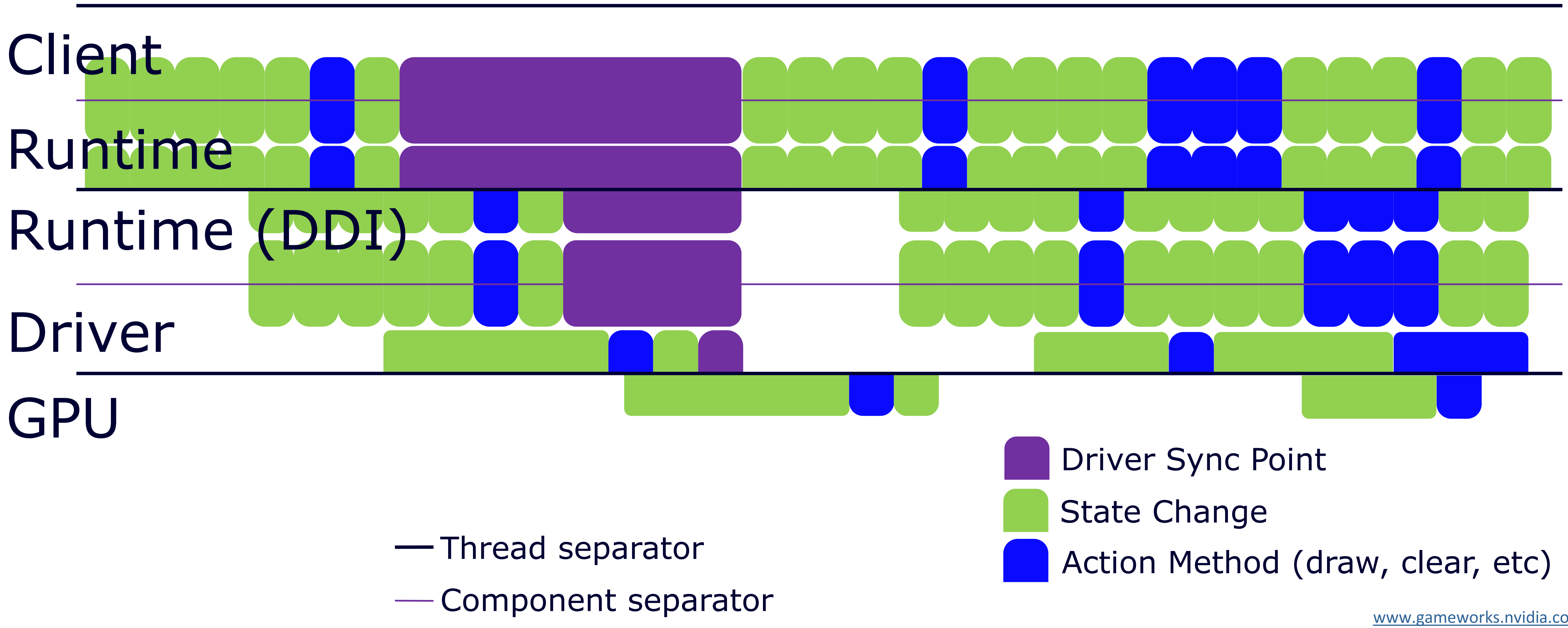
Driver Sync Point

- Major concern in OpenGL
- Minor concern in D3D
- Caused when Client thread would need information available only to Server thread
- In GL, any function that returns a value
- In D3D, certain State-getting operations

Healthy Timeline



Driver Sync Point



CPU-GPU Sync Point: Defined

When an application-side operation requires GPU work to finish prior to the completion of the provoking operation, a **CPU-GPU Sync Point** has been introduced.

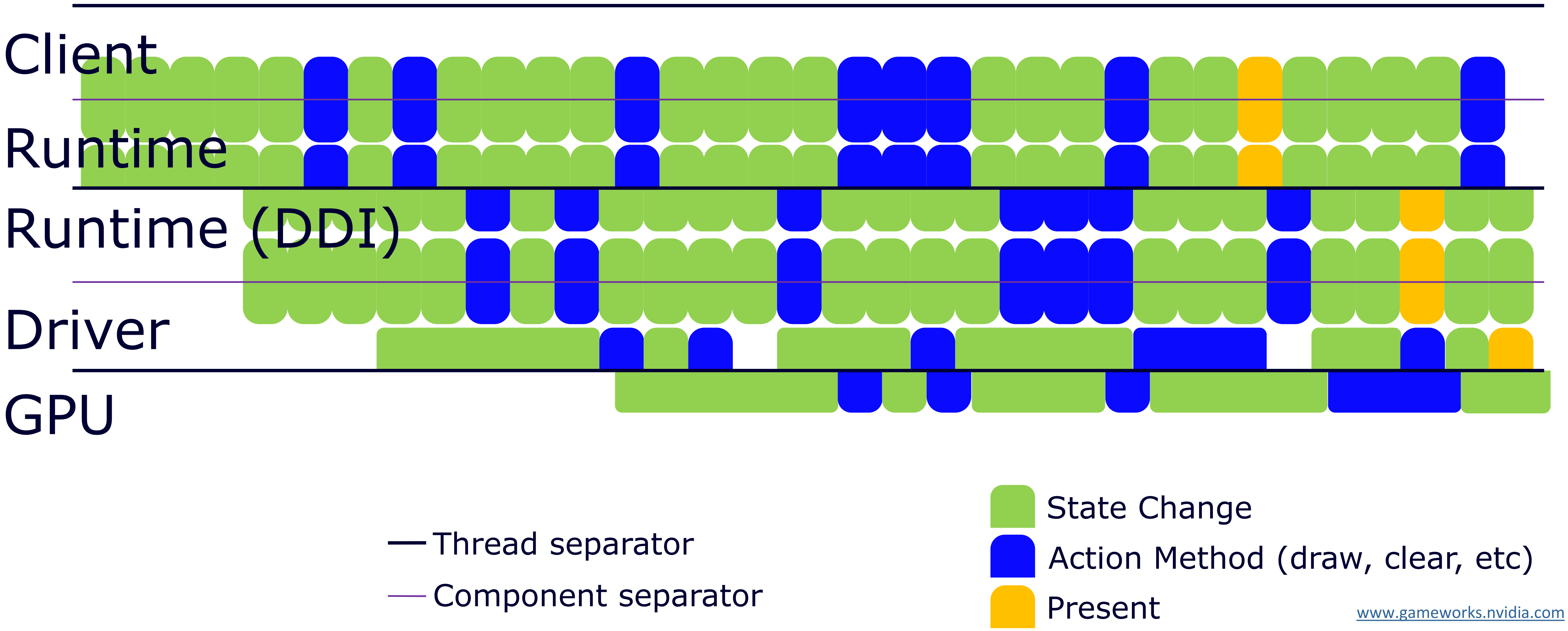
CPU-GPU Sync Point (cont'd)

- Primary causes are buffer updates and obtaining query results
- GPU readback
  - e.g. ReadPixels
  - Locking the Backbuffer
- Complete list of entry points in Appendix

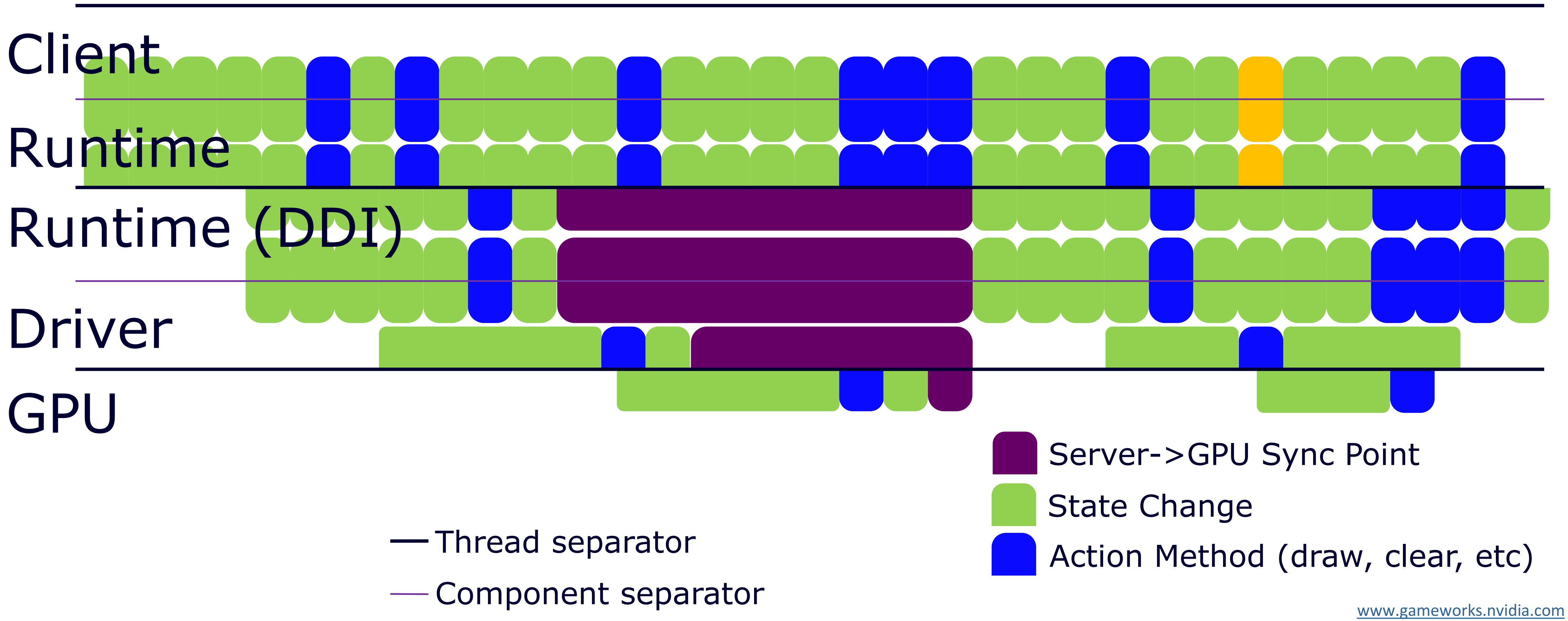
CPU-GPU Sync Point Visualized

- Ideal frame time should be max(CPU time, GPU time)
- Sync points cause this to be CPU Time + GPU Time.

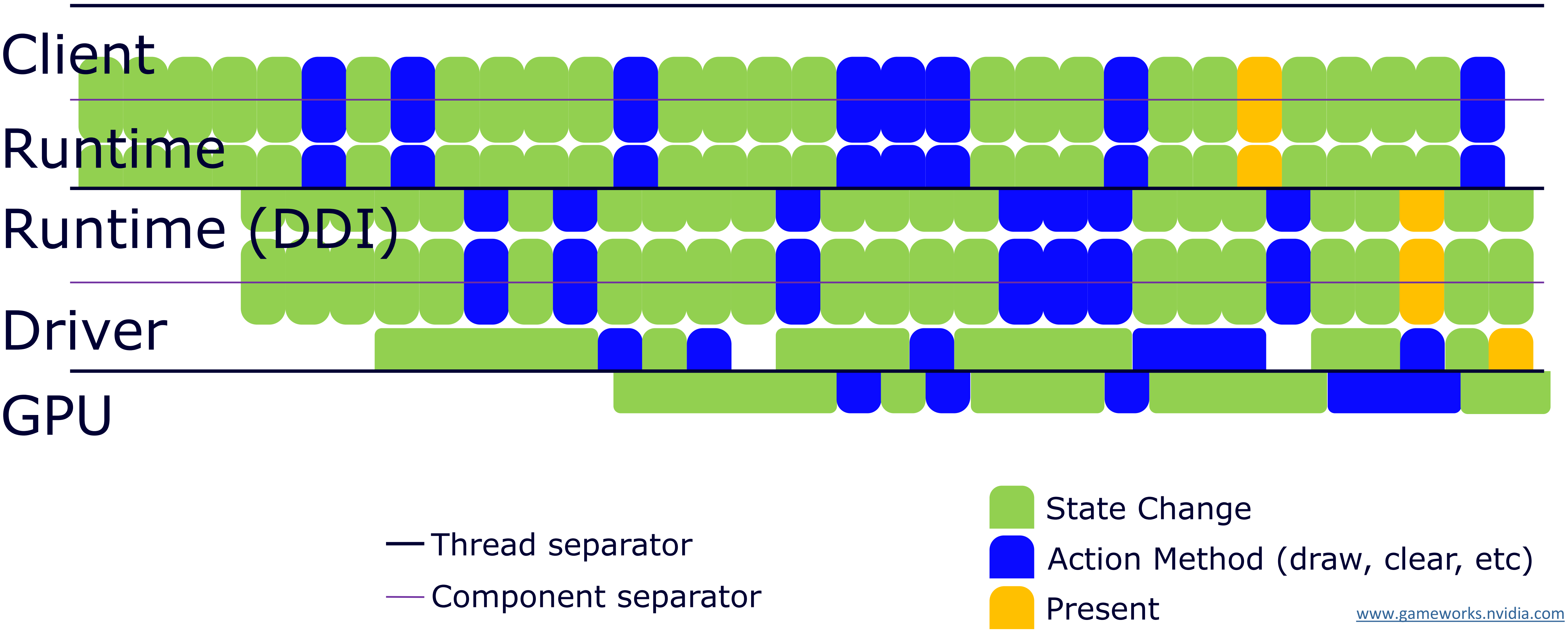
Healthy Timeline



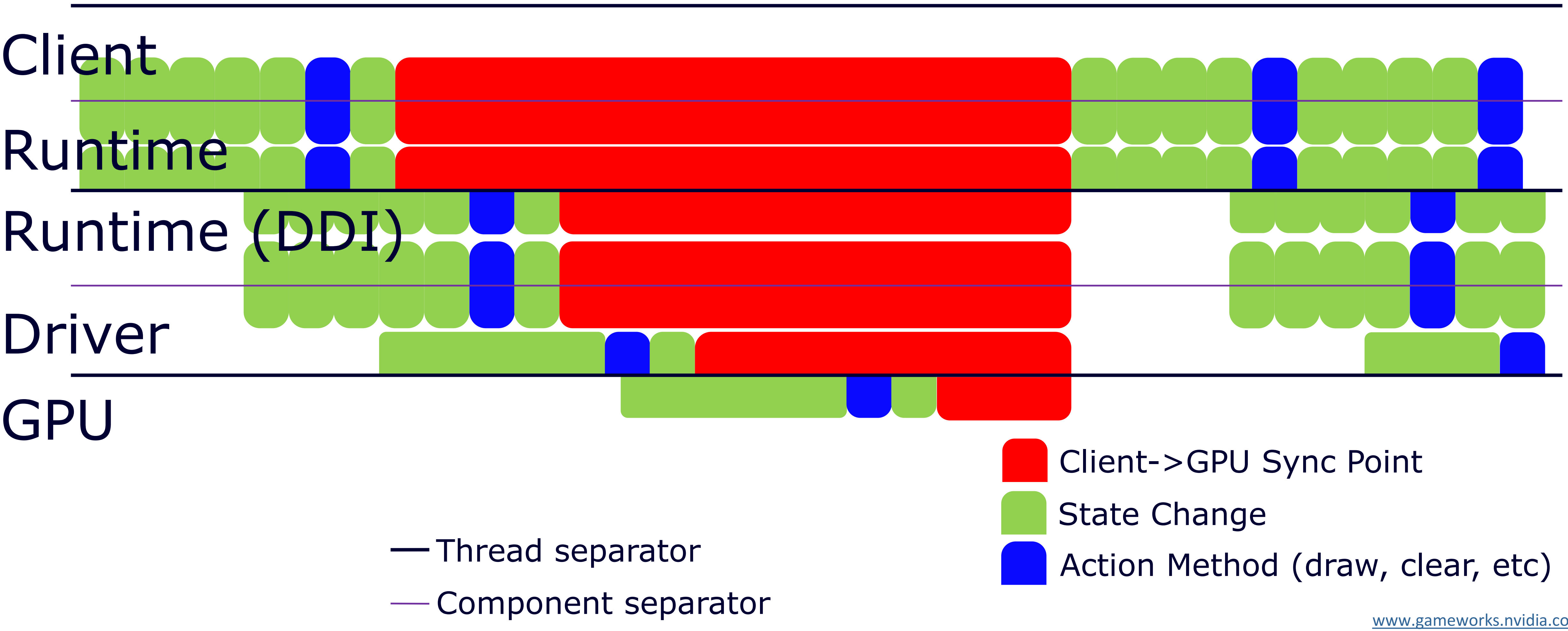
CPU-GPU (Server->GPU) Sync Point



Healthy Timeline



CPU-GPU (Client->GPU) Sync Point



How bad are they, really?

- One CPU-GPU Sync Point can **halve** your framerate.
- The more there are, the harder they are to detect
- They are hard to detect with sampling profilers—the time disappears into Kernel Time.

We get it. They suck. Now what?

- GPU Timestamp Queries to the rescue!

Finding CPU-GPU Sync Points

- For each entry point that could cause a CPU-GPU sync point…
  - Wrap the call with two GPU Timestamp Queries (Don't forget the Disjoint Query)
  - Ideally: record a portion of the stack at the call site
  - Also record CPU timestamps around the call

Finding Sync Points (cont'd)

- Later:
  - Compute the elapsed time between the queries
  - If it is small (< 10 ns), then no GPU kickoff was required
  - If it's larger, a GPU kickoff probably occurred—you've found a CPU-GPU Sync Point!

Code! (Original)

```
ctx->Map(...);
```

Code! (New)

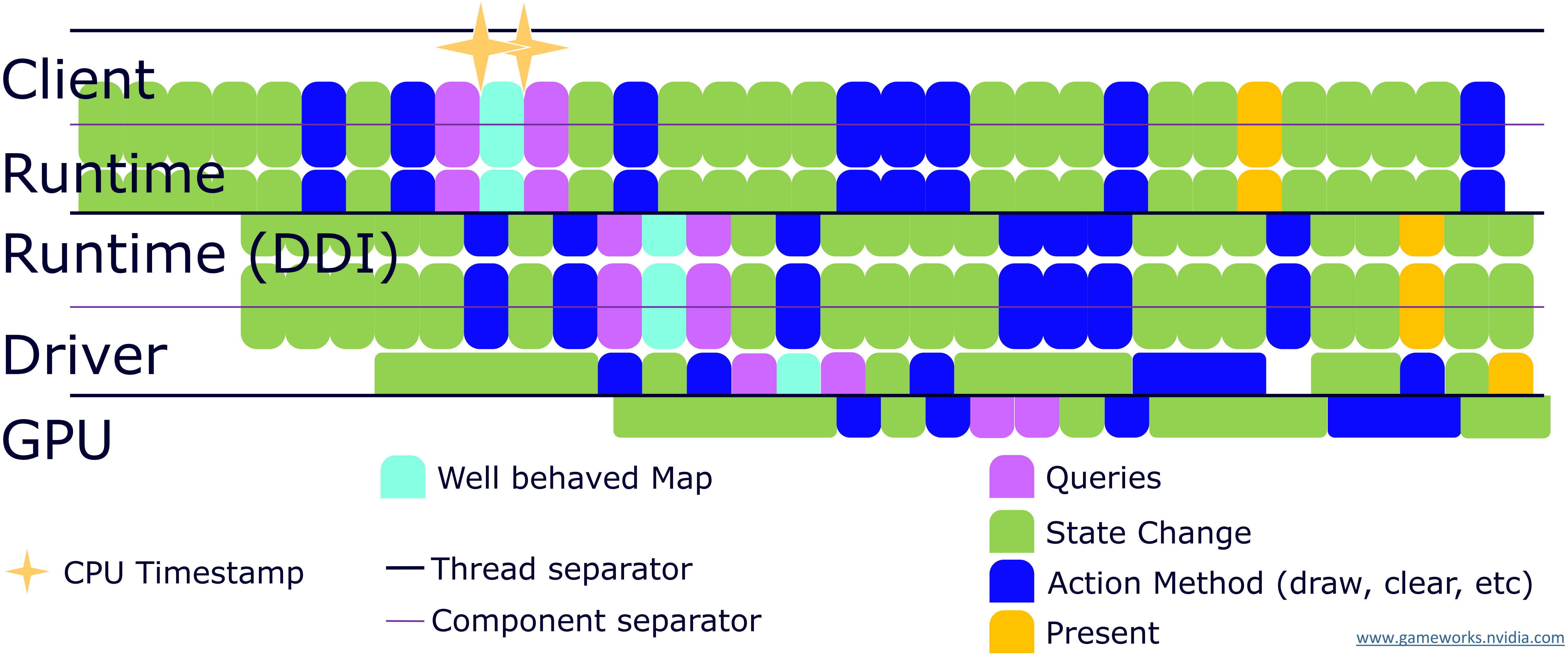
```
ctx->Begin(pDisjoint);
ctx->End(pTimestampBefore);
double earlier = timer::now();
ctx->Map(...);
double cpuElapsed = timer::now() – earlier;
ctx->End(pTimestampAfter);
ctx->End(pDisjoint);
stack = getStackRecord();
gSPChecker->Register(pDisjoint, pTimestampBefore, pTimestampAfter,
                     stack, cpuElapsed);
```

Four Possibilities

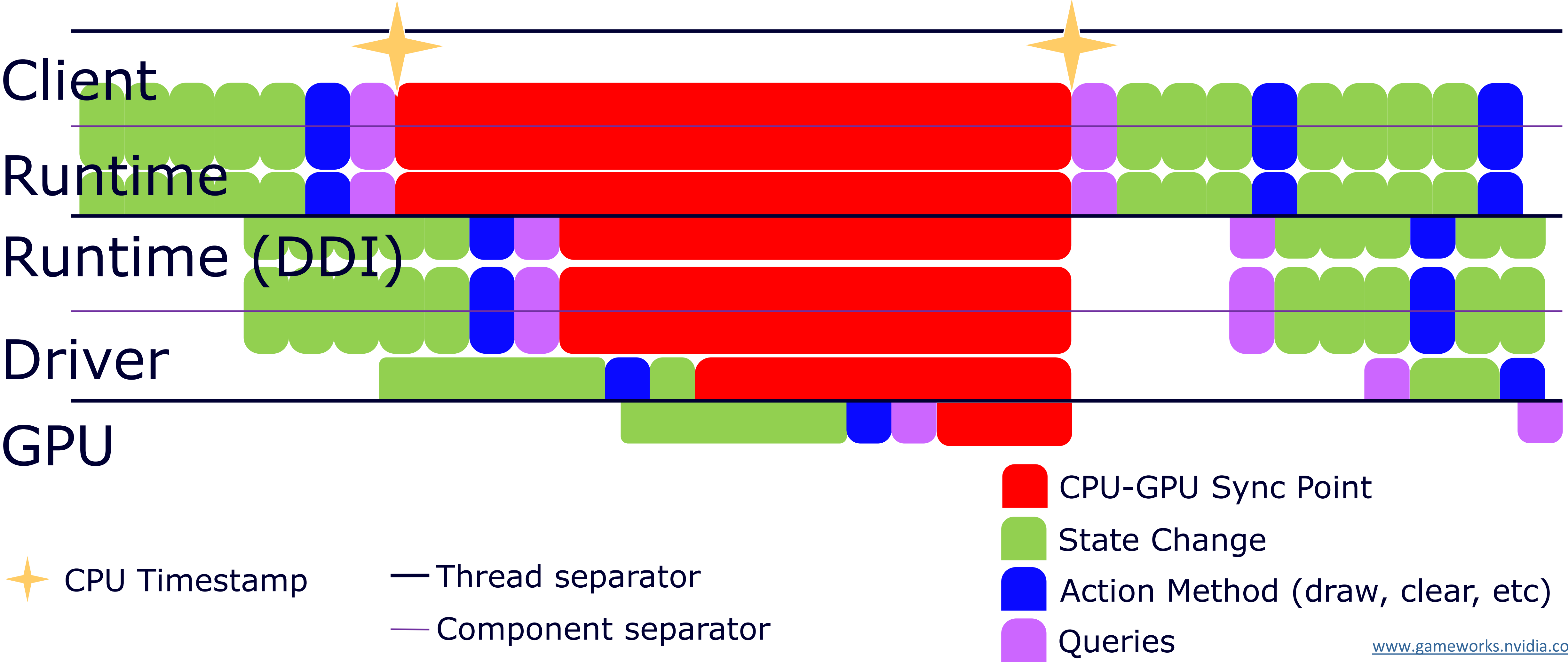
CPU Elapsed	GPU Elapsed	Meaning
Low	~None <10 ns	No problem!
High	~None <10 ns	Possible Driver Sync (Bad)
Low	Low* (~1 us)	Possible Server->GPU Sync (Worse)
High	Low* (~1 us)	Possible Client->GPU Sync (Ugh)

* Let's talk about this in a bit

No problem!


Client
Runtime
Runtime (DDI)
Driver
GPU
Well behaved Map
Queries
State Change
CPU Timestamp
Thread separator
Action Method (draw, clear, etc)
Component separator
Present

Client->GPU Sync Point - detected



Low elapsed GPU?

- GPU is fed commands in FIFO order
- Likely only command caught is WFI
- Which is ~1,000 clocks, or ~1 us or more.
- Subject for future improvements

Split push buffer?

- Two calls right next to each other may wind up in different pushbuffer fragments
- And different GPU kickoffs
- This doesn't hurt our scheme—Timestamp queries occur after "all results of previous commands are realized."
  - This means the timestamp is from the end of the pipeline—not the beginning.

Split Pushbuffer (cont'd)

- Shouldn't be an issue unless you are CPU-bound and barely using the GPU
- Workarounds. Only report:
  - Violators that have either large elapsed GPU times (>1 us); or
  - Hash the call stack, look for those that show up repeatedly.

Fixing CPU-GPU Sync Points

- Adjust flags
  - E.g. D3D9, never lock a default buffer with Flags=0
- Be wary of using nearly all GPU memory
  - May not be enough room for DISCARD operations
- Spin-locking on query results—that's definitely a CPU-GPU Sync Point, regardless of API.

Fixing CPU-GPU Sync Points (cont'd)

- Use NO_OVERWRITE in combination with GPU fences (or event queries) to ensure safe, contention-free updates
- Defer Query resolution until at least one frame later
- Use PBOs to do asynchronous readbacks
  - And wait "awhile" before mapping.

Summary

CPU-GPU Sync Points. Not even one.

Appendix

GPU Timestamp Queries

- Tells you the GPU-time when preceeding operations have completed—including writes to the FB.
- Two timestamp queries adjacent in the pushbuffer will have an elapsed time of 1/(Clock Frequency). (Very, very small).

Problematic D3D9 Entry Points

- Create*^
- IDirect3DQuery9::GetData
- *::Lock
- *::LockRect
- Present

^ Rare, but possible

Problematic D3D11 Entry Points

- ID3D11Device::CreateBuffer*^
- ID3D11Device::CreateTexture*^
- ID3D11DeviceContext::Map
- ID3D11DeviceContext::GetData
- IDXGISwapChain::Present

^ Rare, but possible

Problematic GL Entry Points

- glBufferData^
- glBufferSubData^
- glClientWaitSync
- glFinish

^ Rare, but possible

Problematic GL Entry Points

- glGetQueryResult
- glMap*
- glTexImage*^
- glTexSubImage*^
- SwapBuffers

^ Rare, but possible